Microhabitat Suitability Criteria for Anadromous Salmonids of the Trinity River

By

U.S. Department of Interior
U.S. Fish and Wildlife Service
Coastal California Fish and Wildlife Office
1125 16th Street, Room 209
Arcata, California 95521

Principal Author:
Mark Hampton

Contributing Editors:
Thomas R. Payne
Jeff A. Thomas

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ABSTRACT

Habitat suitability criteria were developed from direct observations of several life stages of anadromous salmonids in the Trinity River above the North Fork Trinity River, California. Observations made between 1985 and 1992 resulted in a total sample size of 1,721 and the creation of depth, velocity, substrate, and cover criteria for chinook salmon, coho salmon, and steelhead fry, juvenile, and spawning life stages, steelhead adult holding, and steelhead juvenile overwintering. The method for final curve creation was compilation of utilization observations, unadjusted for availability and modified in places by professional judgment. Initial attempts to generate habitat preference criteria by the application of the use-to-availability forage ratio concept were abandoned following the creation of unrealistic results and lack of agreement between predictions of suitable habitat and actual juvenile chinook locations. The final curves should be suitable for the evaluation of physical habitat availability in relation to discharge in the existing Trinity River channel below Lewiston Dam.

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INTRODUCTION

Between 1984 and 1996, the U.S. Fish and Wildlife Service (FWS) conducted the Trinity River Flow Evaluation, a study designed to monitor fishery habitat in the Trinity River, California. Results of the study are to be used as a technical basis for reporting to the Secretary of the Interior on the effectiveness of the Secretary's 1981 decision to increase flow releases from Trinity and Lewiston dams. In addition, the FWS was to describe any other habitat rehabilitation measures that would restore fish populations and aquatic habitat in the Trinity River below Lewiston Dam. One task identified during initial study design was the creation of microhabitat suitability criteria that would define the use of physical habitat variables (such as velocity, depth, and substrate or cover) by various fish species and life stages. These criteria can be combined with computer models of hydraulic data from river cross sections (PHABSIM) to compute an index of the capability of various flows to provide suitable physical habitat for fish. The original Plan of Study for the flow evaluation (Appendix A) states that the objective of the task is to "develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for chinook and coho salmon and steelhead trout spawning, incubation, rearing, holding, and migration."

The majority of the study design, field data, and preliminary analyses conducted for the suitability criteria task has been previously reported in Annual Reports (FWS 1985-89, 91) and Hampton (1988), pertinent portions of which are appended (Appendices B-H). Additional unreported data collected during the later years of the flow evaluation and analyses that have affected initial results are included here. The purpose of this report is to document the complete chronology of data collection and analysis efforts, including intermediate steps which were attempted during the course of the study. Microhabitat suitability criteria contained in this report should be considered the final result of the task, incorporating both information acquired during the research and the effects of ongoing evolution in the art of criteria curve development.

STUDY SITES

Fourteen study sites for fish observations and habitat use data collection were selected within three major river segments between Lewiston Dam and the Klamath River confluence at Weitchpec, a distance of approximately 110 miles (Figure 1). The river segments separate the Trinity River hydrologically and by overall character from Lewiston Dam to the North Fork Trinity River, the North Fork to the South Fork Trinity River, and the South Fork to the Klamath River (p. B-1, Appendix B). The study sites were chosen by professional judgment as representative of each segment. Nine sites were located in the segment directly below the dam, two were in the middle segment, and three sites were located in the lower segment. These sites corresponded to locations where transects were placed to collect habitat availability data, although the observation sites generally encompassed longer lengths of the river.

Additional work on the habitat requirements of overwintering steelhead juveniles was performed at five different study sites selected because they contained microhabitat conditions available during the winter season (p. E-2, Appendix E). Two of these study sites were located in side-channels and three were in the main river channel.

METHODS

Habitat use data were collected for all life stages of chinook salmon, coho salmon, and steelhead as fish were encountered within the study sites. Sampling methods included both direct and indirect observational techniques. Direct observations were made underwater by skindivers and above water from the river banks or a raft. During extended periods of poor water clarity, indirect observations were made using a backpack electrofisher or a bag seine. Observations were made when Lewiston Dam releases were between 300 and 450 cfs, a moderate level of flow where diverse depth and velocity habitat conditions were present in the river.

When a fish or group of fish was located, fourteen parameters were measured (or described) and recorded (p. C-3, Appendix C and p. H-5, Appendix H). These included species, size (fork length), water depth (total), water velocity (mean water column), substrate (dominant particle size, subdominant particle size, and percent embedded), and cover type (dominant, subdominant, and quality). Rearing salmonids less than 50 mm (fork length) were considered fry, those larger than 50 mm were considered juveniles, and fish with a fork length greater than 200 mm were considered adults. Schools of fish were treated as single observations at the focal point of the school.

Observations on habitat availability were made in order to generate habitat preference criteria (curves), as was specified in the original Plan of Study (Appendix A). Preference criteria are derived from the ratio of habitat use data over habitat availability data (by physical variable). Availability data were collected initially by taking a minimum of 150 random microhabitat measurements at each study site for each discharge sampled. Sampling locations were determined from previously prepared tables of paired random values of a length-width grid of the sites. Data were collected for essentially the same parameters as for habitat use. This process was extremely time consuming, leading to an alternative which allowed field efforts to be allocated more toward collection of habitat use data. Using this alternative, physical habitat availability data were obtained from hydraulic simulation models which were run on transects located within the fish observation study sites. The method is described in detail in the 1986 Annual Report (p. C-9, Appendix C) and includes a comparison of the two approaches showing the similarity in estimates of habitat availability. Results of the comparison are also reported in Aceituno and Hampton (1987) and Hampton (1988). The latter report is included here as Appendix H.

Initial data frequencies (bar histograms) of habitat use by each species and life stage were constructed following the guidelines presented by Bovee and Cochnauer (1977). Frequency intervals for depth and velocity were calculated using the Sturges Rule, as cited by Cheslak and Garcia (1987). Resulting frequency bar histograms were subjected to two series of three point running mean filters and normalized to a maximum value of one. For cover, a simple frequency bar histogram was constructed using only the dominant cover type. Two frequency bar histograms were constructed for substrate, one a paired histogram of dominant and subdominant codes and another a simple bar of percent embedded in fines. These were also normalized to a maximum value of one, with each remaining interval given a value proportional to its relative occurrence.

RESULTS

The first two years of data collection in all three segments produced 2,418 fish observations and associated microhabitat measurements for four salmonid species in four life stages (p. C-7, Appendix C). This number was later pared to 1,809 observations for three salmonid species in three life stages (p. H-13, Appendix H) by the removal of data for brown trout and holding adult fish. Subsequently, the 1988 data set was further restricted to: 1) observations made above the North Fork Trinity River (where habitat availability data for preference criteria could be generated from hydraulic simulation modeling), and 2) data collected by direct observation only. Data collected in later years for steelhead fry, overwintering steelhead juveniles, and holding adult steelhead were added, resulting in a final total of 1,721 observations used to develop habitat suitability criteria (Table 1).

Chinook salmon fry were most often found along the edge of the stream where very slow water velocities (Figure 2.1) and abundant cover items were present. Woody debris, undercut banks, and cobble substrates provided chinook fry with velocity shelters and escape cover from surface-feeding predators. As chinook salmon grew larger they became less dependent on edge habitats and began to use areas with higher water velocities in deeper water (Figure 2.2). Object cover still played a key role in providing velocity shelters in deep run and riffle habitats. In deep pool habitats, schools of juvenile chinook salmon positioned themselves in relationship to eddies and shear velocity zones where food items could be easily taken in the drift. In pool habitats the majority of juvenile salmon would feed near the water surface and would flee to deep water when frightened from above. At night, chinook salmon fry and juveniles congregated in slow velocity habitats close to the river bed or cover.

Table 1. Summary of total fish observations collected 1985-1992 in the Trinity River, CA, above the North Fork and used for criteria curve development.

Species	Life Stage	Number of Observations
Chinook Salmon	Fry	345
	Juvenile	251
	Spawning	311
Coho Salmon	Fry	131
	Juvenile	82
	Spawning	107
Steelhead	Fry	80
	Juvenile	185
	Adult Holding	44
	Spawning	88
	Over-wintering Juvenile	97
Total		1,721

For redd construction, spawning chinook salmon used gravels and cobbles two-to-six inches in diameter that were less than 40% embedded in fines. The majority of redds were located in water from 0.5 to 2.5 feet deep (Figure 2.3). The range of water velocities measured at established redds was relatively broad, but the majority had mean column velocities between 0.75 and 2.5 feet per second (fps). Areas close to the river banks were favored for redd excavation by spawning chinook over open areas in midstream.

Coho salmon fry (Figure 2.4) selected similar microhabitats as chinook salmon fry and the two species were often found together. Aggressive behavior between the species was rarely observed. As coho salmon became larger they did not shift their habitat selection to areas of faster velocity as did chinook salmon. Juvenile coho were usually found in low velocity conditions such as were present in backwaters, side-channels, and along stream edges adjacent to slow runs and pools (Figure 2.5). These microhabitats generally contained abundant cover in the form of woody debris, aquatic vegetation, and overhanging vegetation. Substrates were composed of fine sand, silt, organic debris, or larger particles that were highly embedded in fines. Because of differences in habitat selection, spatial segregation between juvenile coho and chinook salmon was common.

Nearly all coho salmon spawning activity takes place within the first three miles below Lewiston Dam where many artificially constructed spawning riffles are located. Spawning coho used one-to-three inch gravels and cobbles that were less than 20% embedded in fines. Coho salmon spawned in areas that were both slightly shallower and slower moving than those used by chinook. Most coho redds were constructed in depths ranging from 0.5 to 2.0 feet, with water velocities between 0.6 and 2.0 fps (Figure 2.6).

Steelhead fry preferred edge habitats adjacent to riffles and swifter runs where they selected focal points close to the substrate or cover items providing velocity shelters. Unlike the fry of chinook or coho salmon, steelhead were often observed in the turbulent conditions found in shallow riffles. Overall, the depths utilized by steelhead fry were shallower than those used by salmon fry and the water velocities were significantly higher (Figure 2.7). Steelhead fry were rarely observed in monotypic habitats such as long, slow runs or pools.

Juvenile steelhead preferred run, riffle, and riffle-pool transition habitats that provided diverse velocity conditions. They showed a distinct preference for higher water velocities than juvenile salmon (Figure 2.8). Juvenile steelhead were efficient in their use of velocity shelters. In riffles and across the tail end of run habitats, object cover (e.g., boulders, large cobbles) was used to establish feeding stations which were actively defended. When found in riffle-pool transition habitats, juvenile steelhead were usually positioned below the ledge located at the upper boundary of the pool. Here the fish were sheltered from the swifter surface current which conveyed invertebrate drift from the riffle upstream. Microhabitats selected by steelhead juveniles in the winter season had slower water velocities than those used in other seasons (Figure 2.11) and they were characterized by clean cobble substrates. Overwintering fish were almost always located underneath cobbles or boulders.

Habitat suitability criteria were developed for both spawning and holding adult steelhead. Spawning steelhead preferred gravel from one-to-three inches in diameter that was less than 20% embedded in fines. The range of depths at which redds were constructed was relatively narrow and generally shallower than for the salmon species (Figure 2.9). Preferred velocities were much the same as for coho salmon. It is apparent from the depth and velocity distributions displayed for the 44 holding steelhead adults observed (Figure 2.10) that this life stage is very flexible in its microhabitat requirements. Adult steelhead were found holding in water from 1.5 to 10 feet deep with water velocities ranging from 0.3 to 3.5 fps.

CRITERIA DEVELOPMENT

The development of the habitat suitability curves went through several iterations during the course of the twelve-year Flow Evaluation. The original plan to derive preference curves by the ratio of use-to-availability ultimately failed. Problems, mostly related to small sample sizes at the tails of the distributions, resulted in preference curves for some species and life stages that were unduly influenced by the habitat selection of only a few individuals within the sampled population. While some of these curves were similar to those derived from the utilization data alone, many showed highly unusual suitability values that seriously contradicted the majority of the use observations (Appendix H).

The velocity preference curves for spawning (all three species) were particularly unusual (Figure 20 of Appendix H). An attempt was made to correct this problem (Figure 21of Appendix H). Nonparametric tolerance limits were used to obtain a more normal shaped curve. Two other problematic preference curves were the depth functions for juvenile chinook salmon (Figure 6 of Appendix H) and steelhead (Figure 16 of Appendix H). These criteria indicate that juvenile chinook salmon and steelhead did not exhibit a strong preference for a particular depth range. Both depth preference curves were therefore modified to retain the highest suitability value of 1.0 for depths greater than 1.4 feet for juvenile chinook and greater than 2.3 feet for juvenile steelhead (Figure 22 of Appendix H).

The need for these modifications led to concern over the use of forage ratios to derive preference criteria. This was reflective of the debate on this issue which was occurring at the time within the instream flow modeling community (Morhardt and Hanson, 1988). A validation study was undertaken to determine if a relationship existed between juvenile chinook salmon use (i.e. density) of discrete river areas (cells) and cell suitability as defined by the preference criteria. The methods employed and the results of this study are reported in the 1989 annual report (Appendix F). Findings indicated that there was poor correlation between juvenile salmon density and habitat suitability, suggesting that the preference criteria developed for juvenile chinook would need further refinement in order to better reflect habitat suitability (p. F-12, Appendix F).

Ultimately, these concerns led to a decision to revert to utilization criteria alone for future use in physical habitat analyses and to abandon direct adjustment for availability for any of the variables. By 1988, when curves were developed for overwintering juvenile salmonids, only utilization data were used and the concept of using forage ratios was implicitly abandoned (p. E-5, Appendix E). This decision is consistent with that reached by Bovee (1995), who recommended, based on results of curve transferability testing, that preference criteria developed using a forage ratio no longer be used in PHABSIM applications. A second validation study, undertaken in 1991 and using the habitat use curves to determine cell suitability, found a positive correlation between juvenile chinook density and habitat suitability (Appendix G). Some effects of the bias of habitat availability on the utilization data probably remain in the final use criteria curves due to the original study design, but retention of the use data in its unadjusted form (with some exceptions) is believed to be better than accepting the unsatisfactory results of the ratio method. The final criteria curves should be suitable for the evaluation of physical habitat availability in relation to discharge in the Trinity River below Lewiston Dam.

Utilization data alone, with the exceptions noted below, were used to develop the final habitat suitability criteria for evaluation of anadromous salmonid physical habitat availability in the Trinity River. Final depth and velocity criteria curves for all species and life stages having both minimally acceptable sample sizes (approximately 50) and well-distributed data (i.e. not excessively scattered or uneven) are presented together in Figures 3.1 through 3.3. Coordinate points for these curves are presented in Tables 2.1 through 2.11. Substrate and cover criteria remained unchanged since 1988 and are presented in Hampton (1988)(Appendix H).

The exceptions to stand-alone utilization as final criteria were for depth for juvenile chinook and coho salmon, overwintering juvenile steelhead, and holding adult steelhead. For these curves, depth was retained at a 1.0 suitability at all depths greater than that providing the initial 1.0 value, so that deep water pool habitats would not be eliminated as potential habitat areas. In contrast, the depth suitability for rearing juvenile steelhead was not altered because of the observed heavy reliance by this species/life stage on shallow riffle and riffle-pool transition areas.

REFERENCES

Aceituno, M., and M. Hampton. 1987. Validation of habitat availability determinations by comparing field observations with hydraulic model (IFG-4) output. Pp. 322-334 *in* K.D. Bovee and J. Zuboy [eds.], Proceedings of a workshop on the development and evaluation of habitat suitability criteria. U.S. Fish Wildl. Serv. Biol. Rep. 88(11). 407 pp.

Bovee, K.D., and J.M. Bartholow. 1995. IFIM Phase III Study Implementation. Pages 191:255 *in* K.D. Bovee (editor) A comprehensive overview of the Instream Flow Incremental Methodology. National Biological Service, Fort Collins, Colorado.

Bovee, K.D., and T. Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: Fisheries. Instream Flow Information Paper No. 3. U.S. Fish Wildl Serv. FWS/OBS-77/63.

Cheslak, E., and J. Garcia. 1987. Sensitivity of PHABSIM model output to methods for fitting functions of curves to species preference data. Pp. 259-286 *in* K.D. Bovee and J. Zuboy [eds.], Proceedings of a workshop on the development and evaluation of habitat suitability criteria. U.S. Fish Wildl. Serv. Biol. Rep. 88(11). 407 pp.

FWS. 1985. Trinity River Flow Evaluation Annual Report, Sacramento, California. 26 pp.

FWS. 1986. Trinity River Flow Evaluation Annual Report, Sacramento, California. 30 pp.

FWS. 1987. Trinity River Flow Evaluation Annual Report, Sacramento, California. 192 pp.

FWS. 1988. Trinity River Flow Evaluation Annual Report, Sacramento, California. 56 pp.

FWS. 1989. Trinity River Flow Evaluation Annual Report, Sacramento, California. 123 pp.

FWS. 1991. Trinity River Flow Evaluation Annual Report, Sacramento, California. 57 pp.

Hampton, M. 1988. Development of habitat preference criteria for anadromous salmonids of the Trinity River. U.S. Fish and Wildlife Service, Sacramento, California. 93 pp.

Morhardt, J.E., and D.F. Hanson. 1988. Habitat availability considerations in the development of suitability criteria. Pp. 392:407 *in* K.D. Bovee and J.R. Zuboy [eds.], Proceedings of a workshop on the development and evaluation of habitat suitability criteria. U.S. Fish Wildl. Serv. Biol. Rep. 88(11). 407 pp.

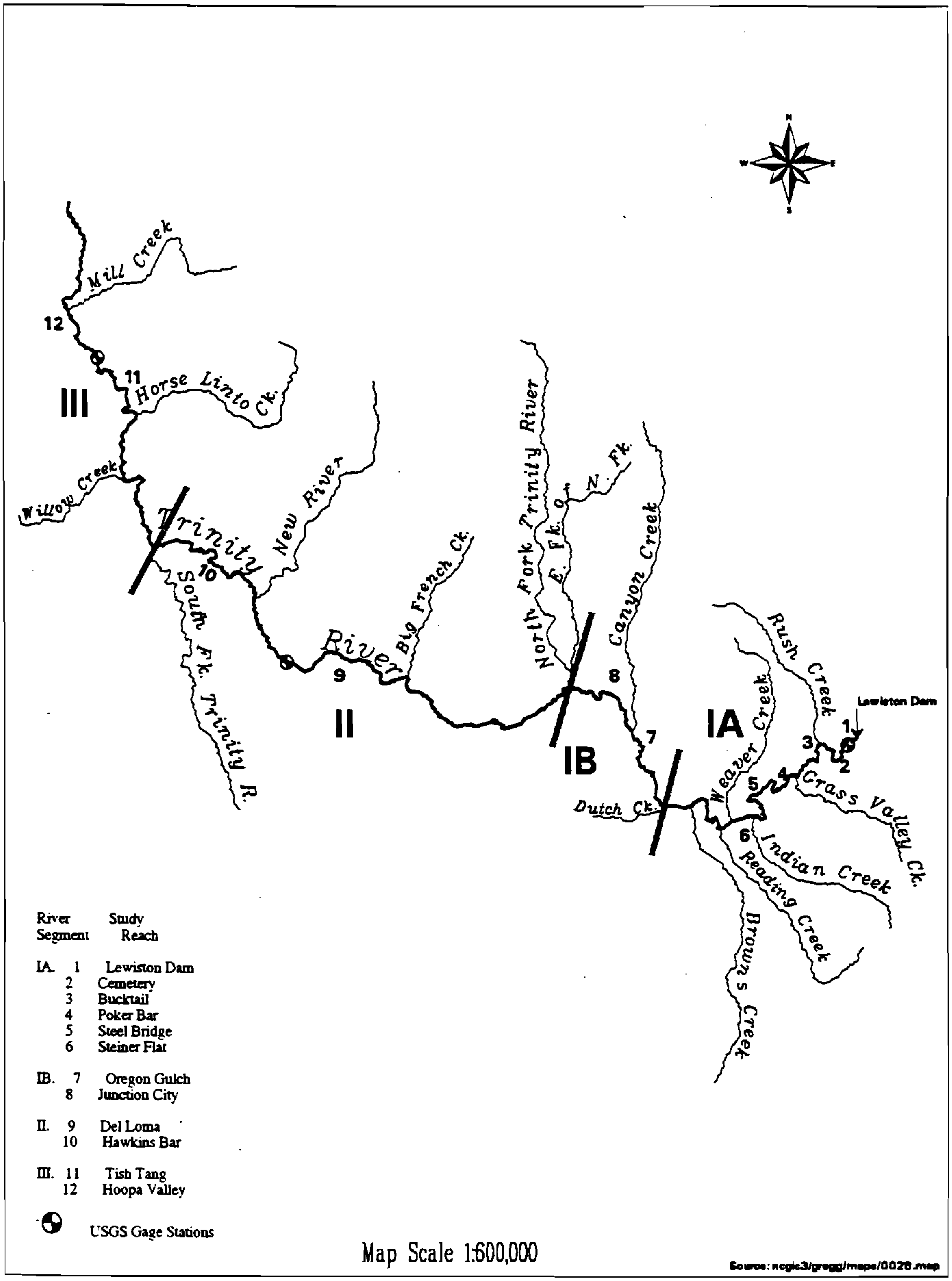


Figure 1. Map of study segments and reaches in the Trinity River basin.

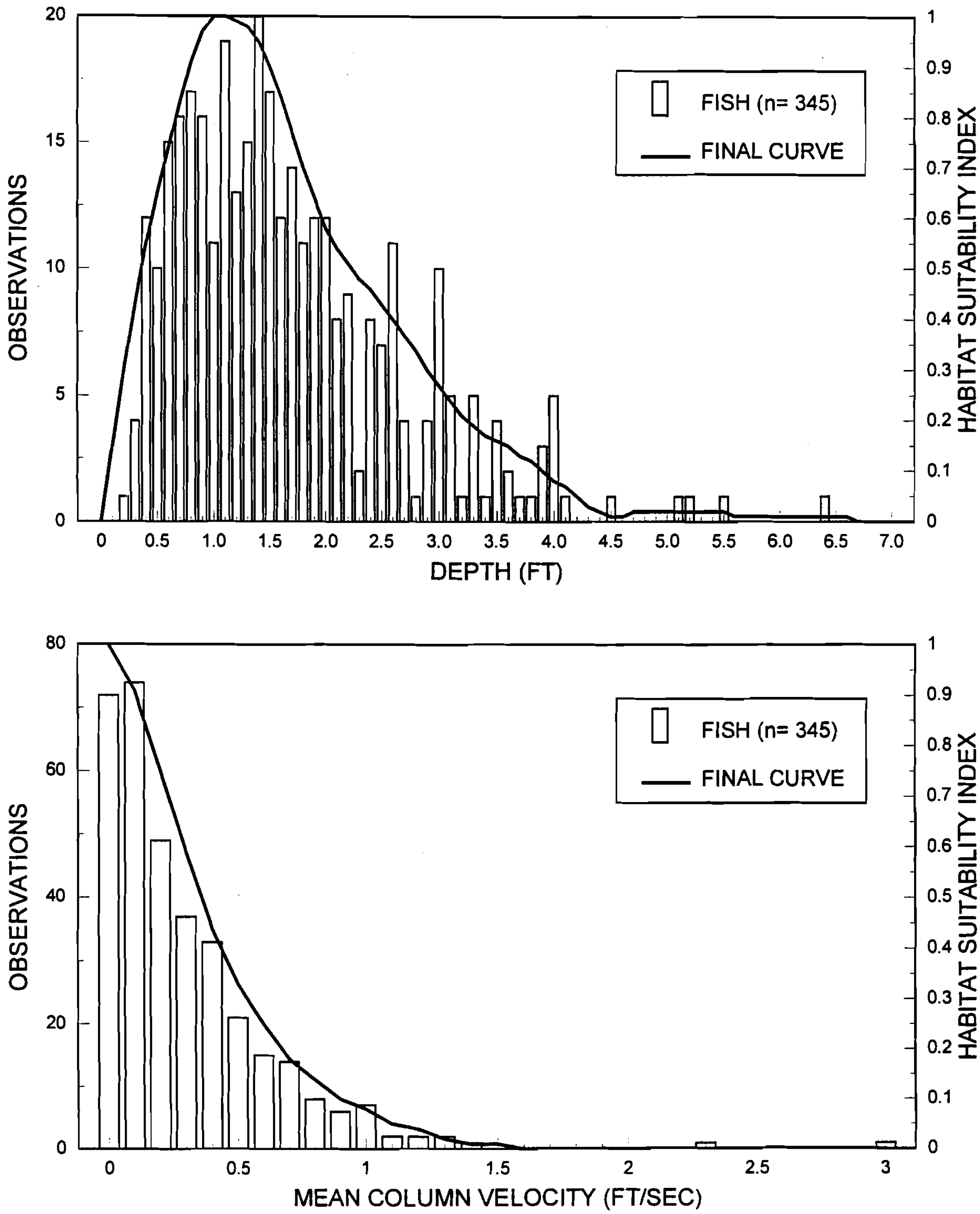


Figure 2.1 Chinook salmon fry observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

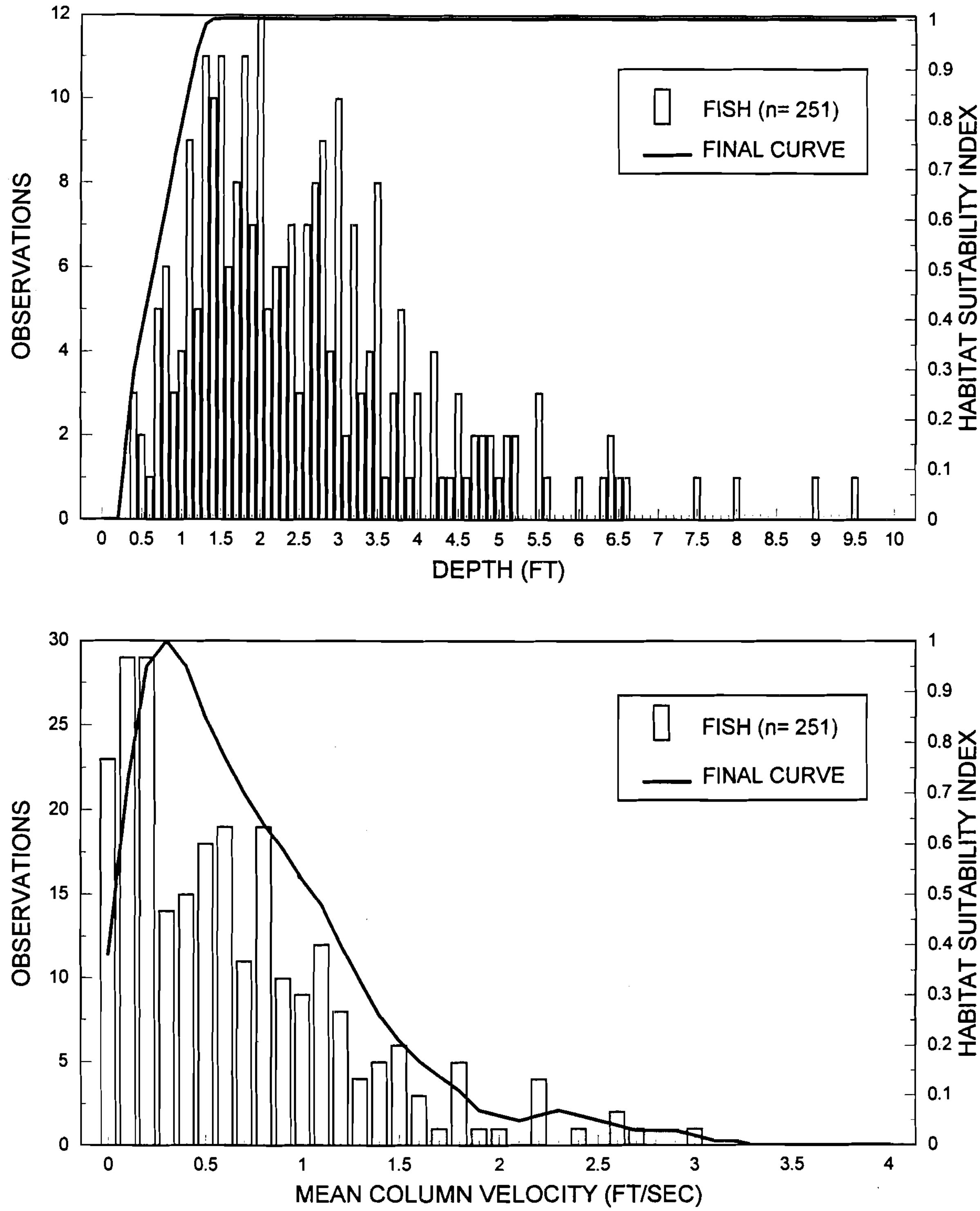
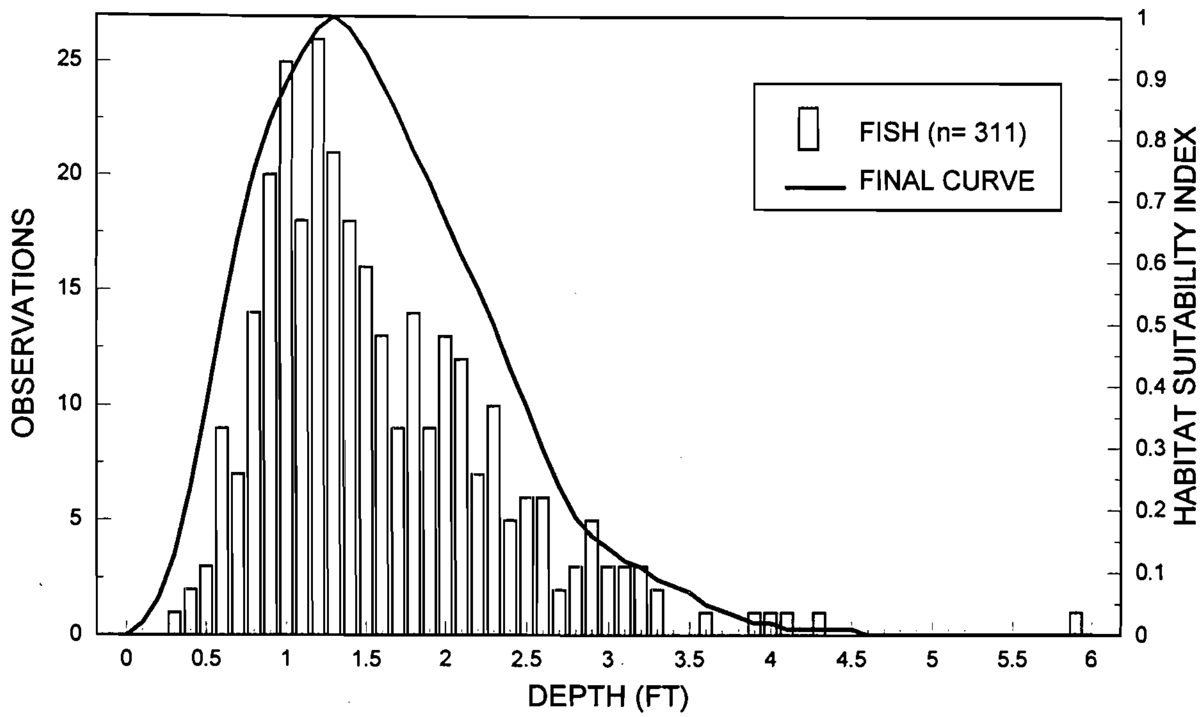


Figure 2.2 Chinook salmon juvenile observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.



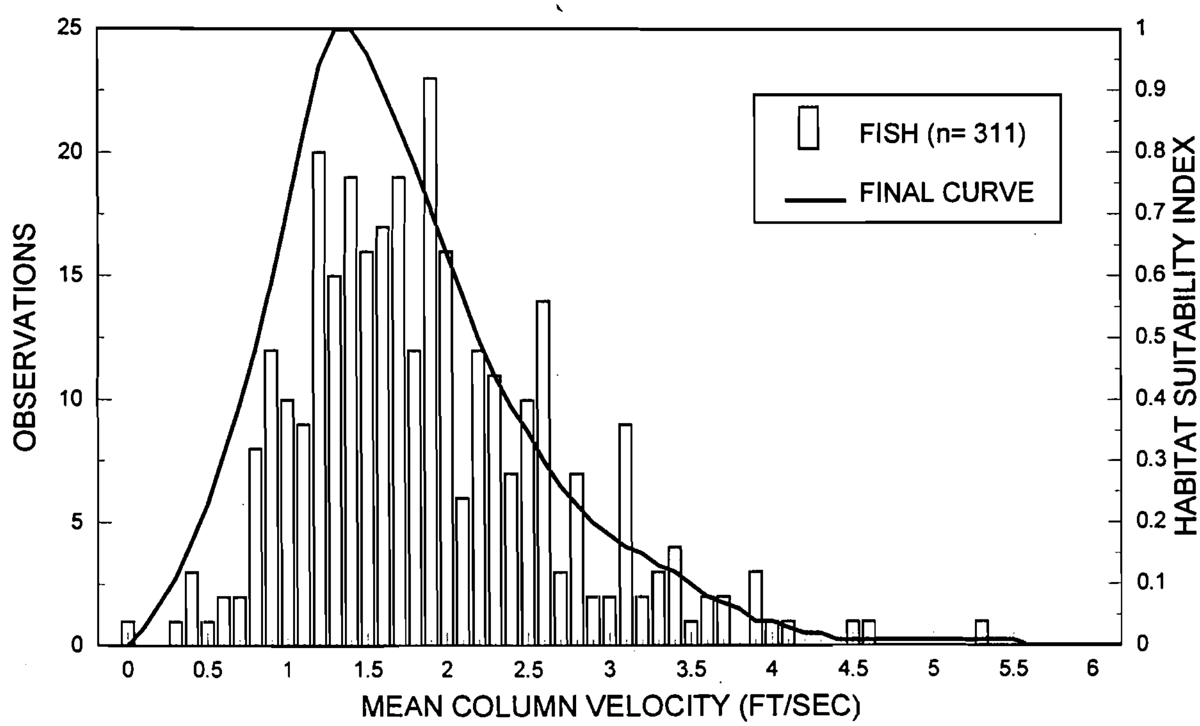
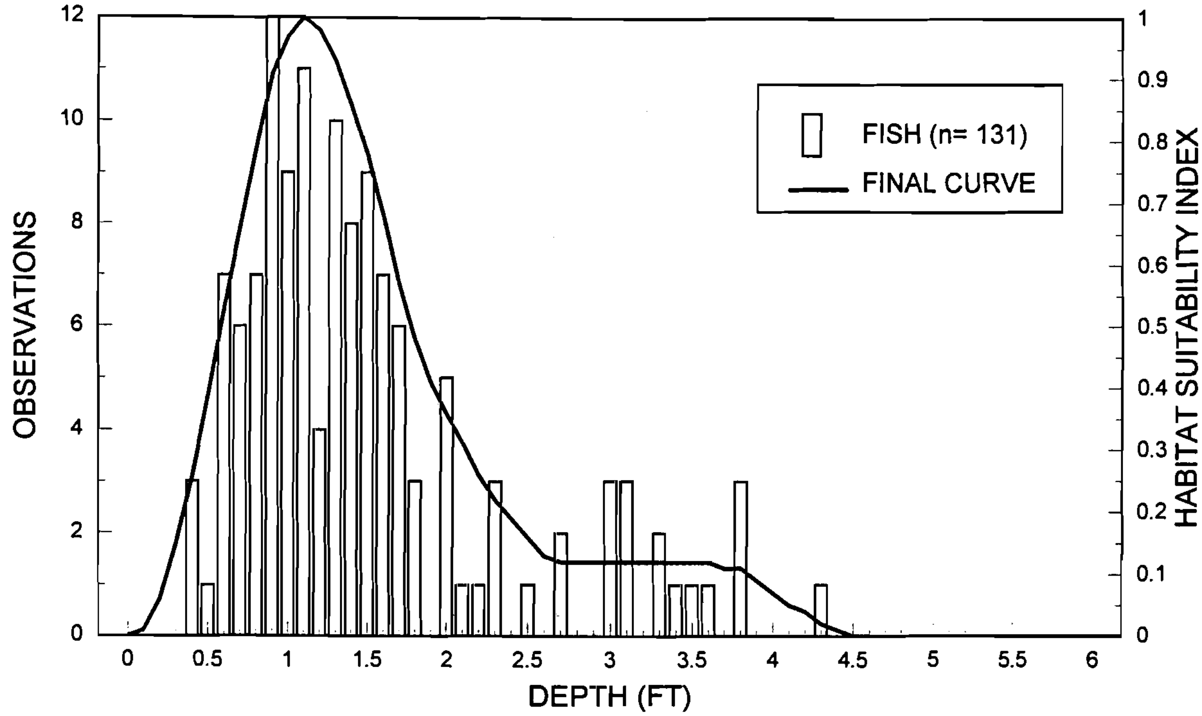


Figure 2.3 Chinook salmon spawning observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.



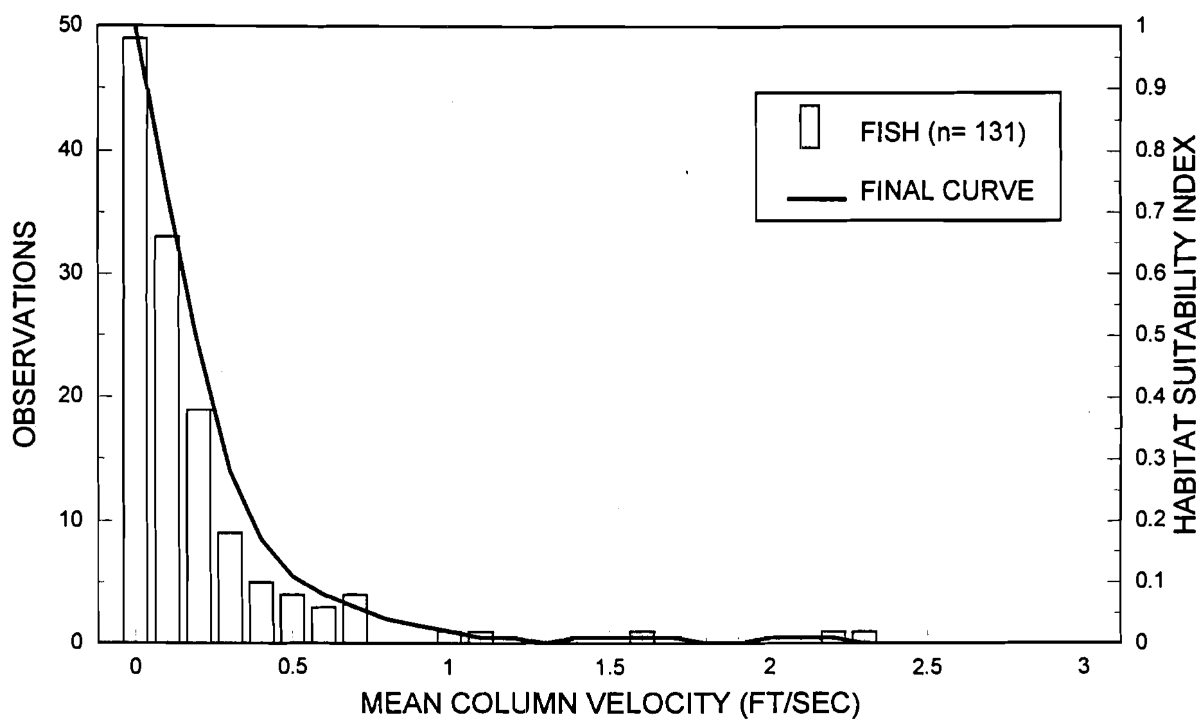


Figure 2.4 Coho salmon fry observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

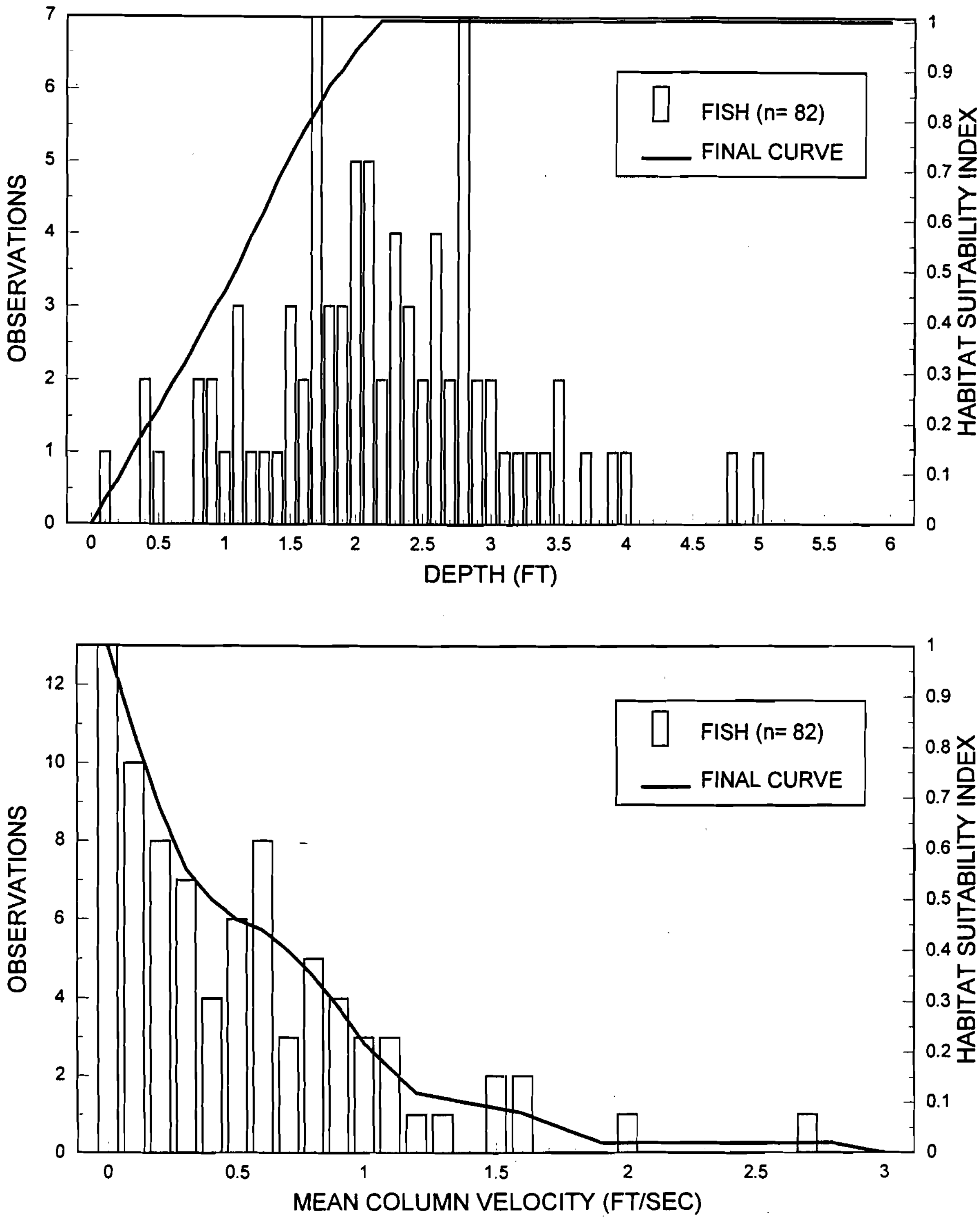


Figure 2.5 Coho salmon juvenile observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

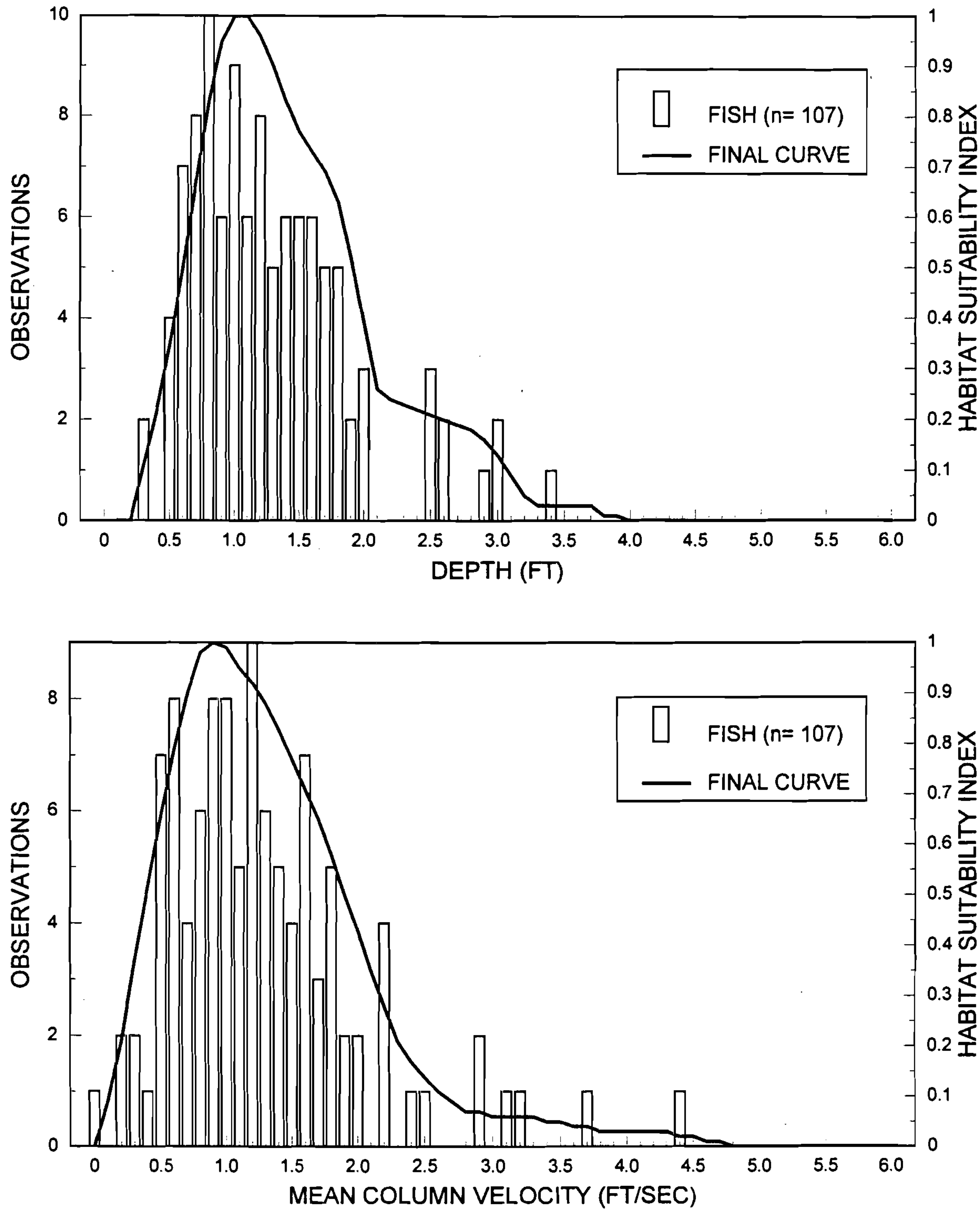


Figure 2.6 Coho salmon spawning observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

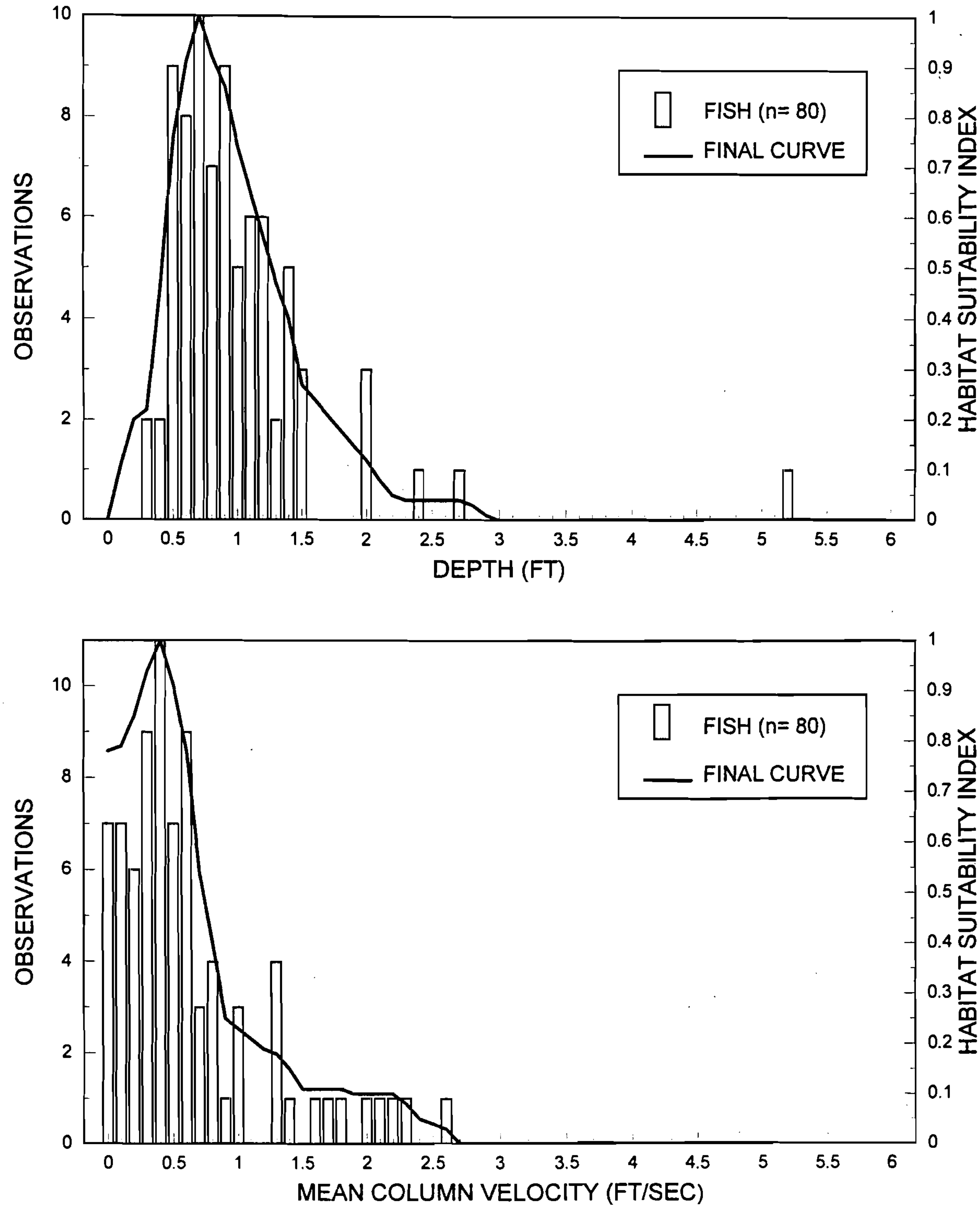


Figure 2.7 Steelhead fry observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

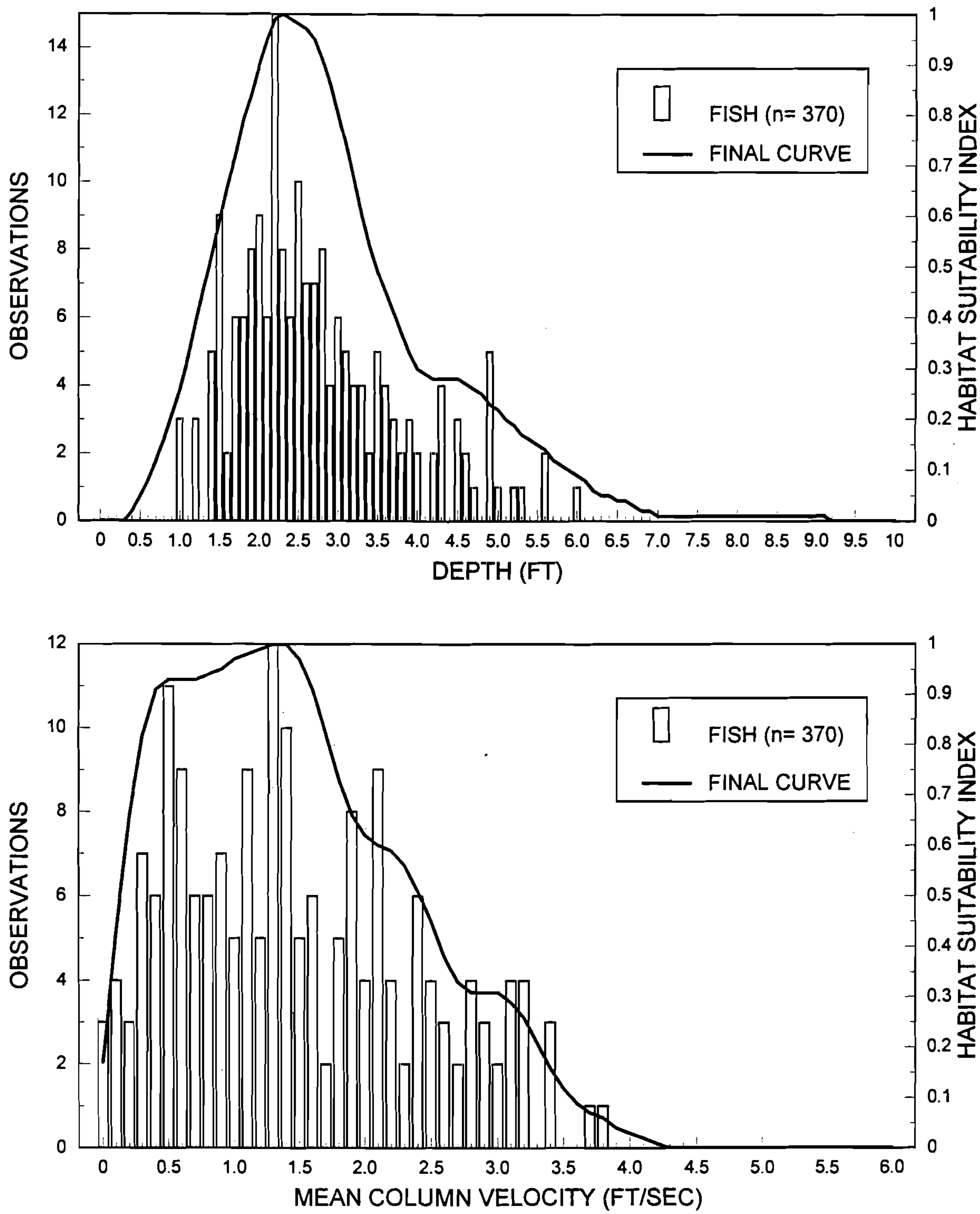
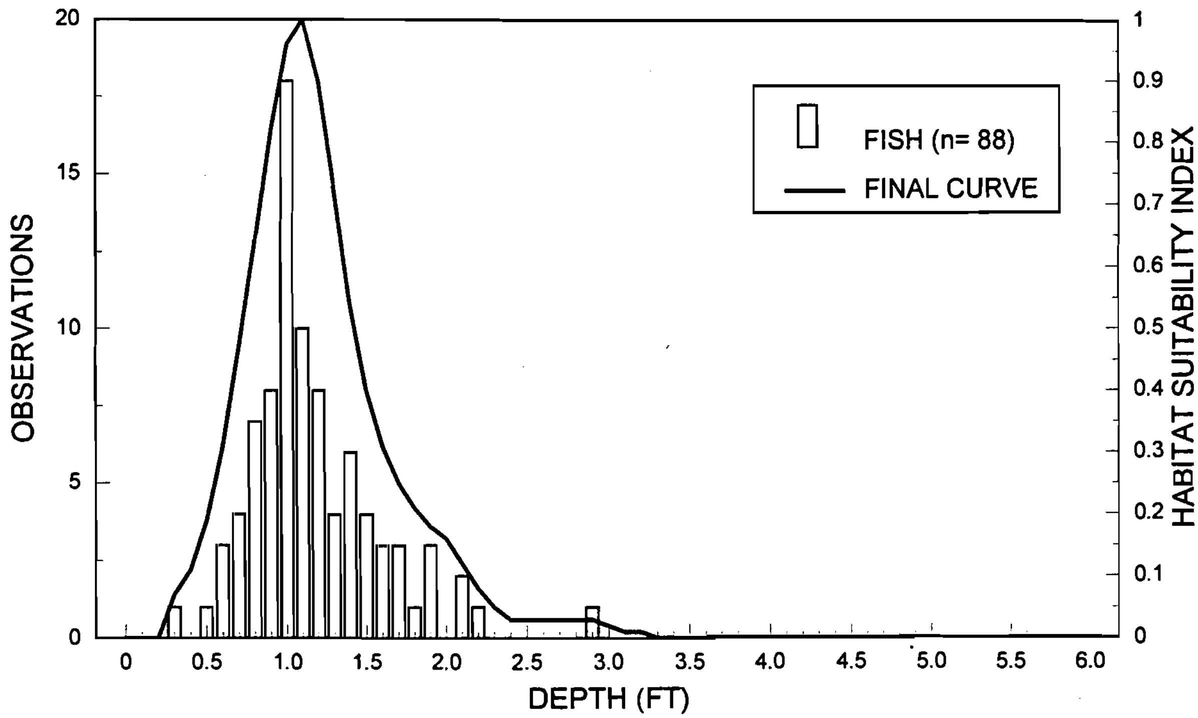


Figure 2.8 Steelhead juvenile observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.



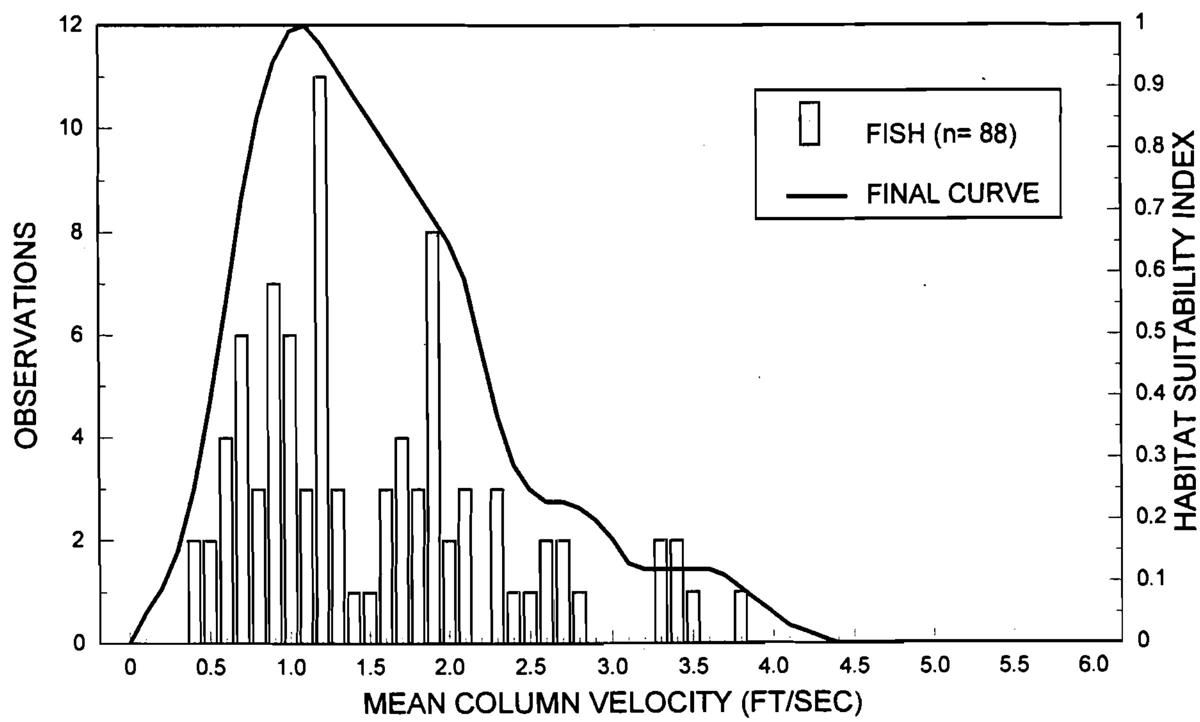


Figure 2.9 Steelhead spawning observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

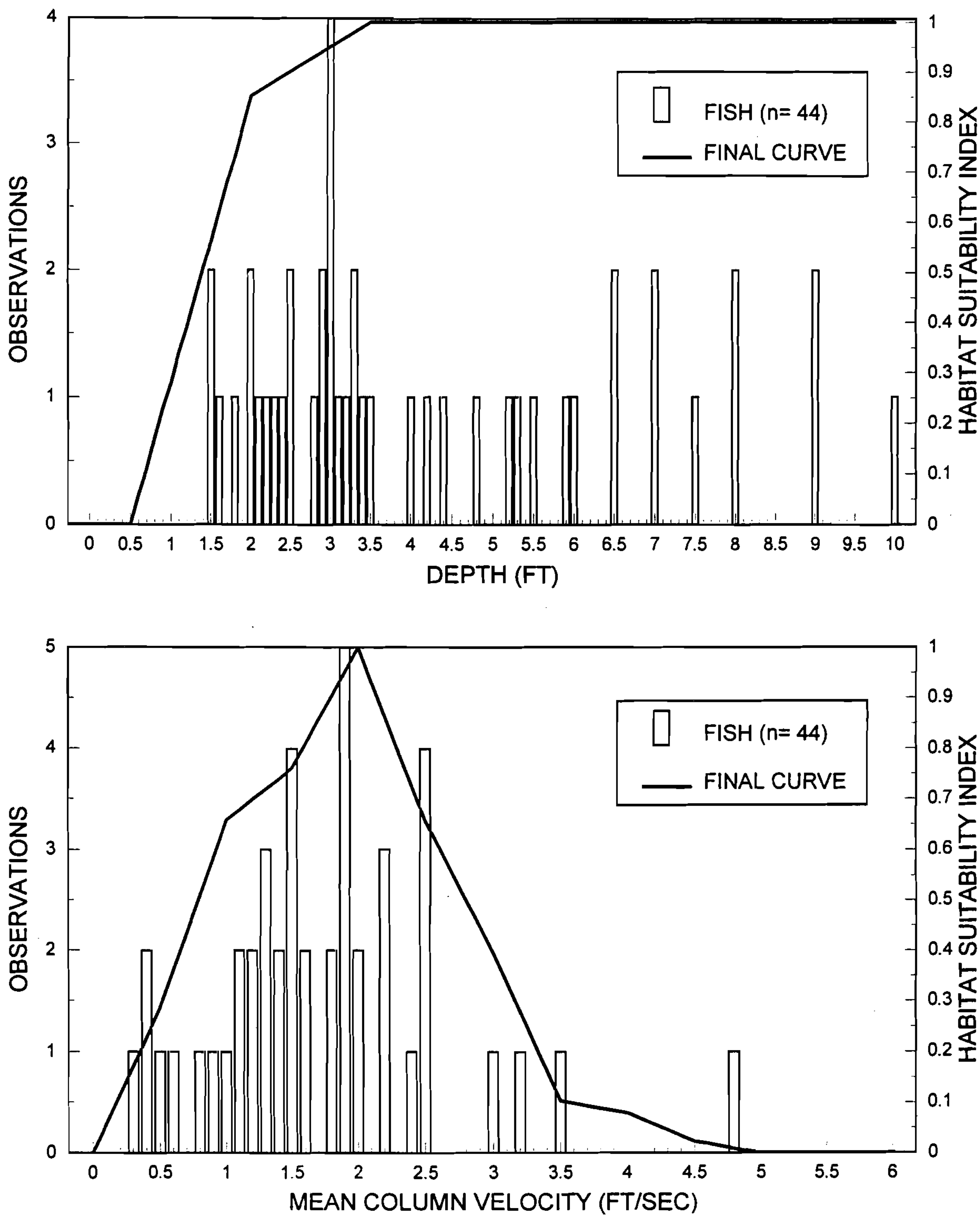


Figure 2.10 Steelhead adult holding observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

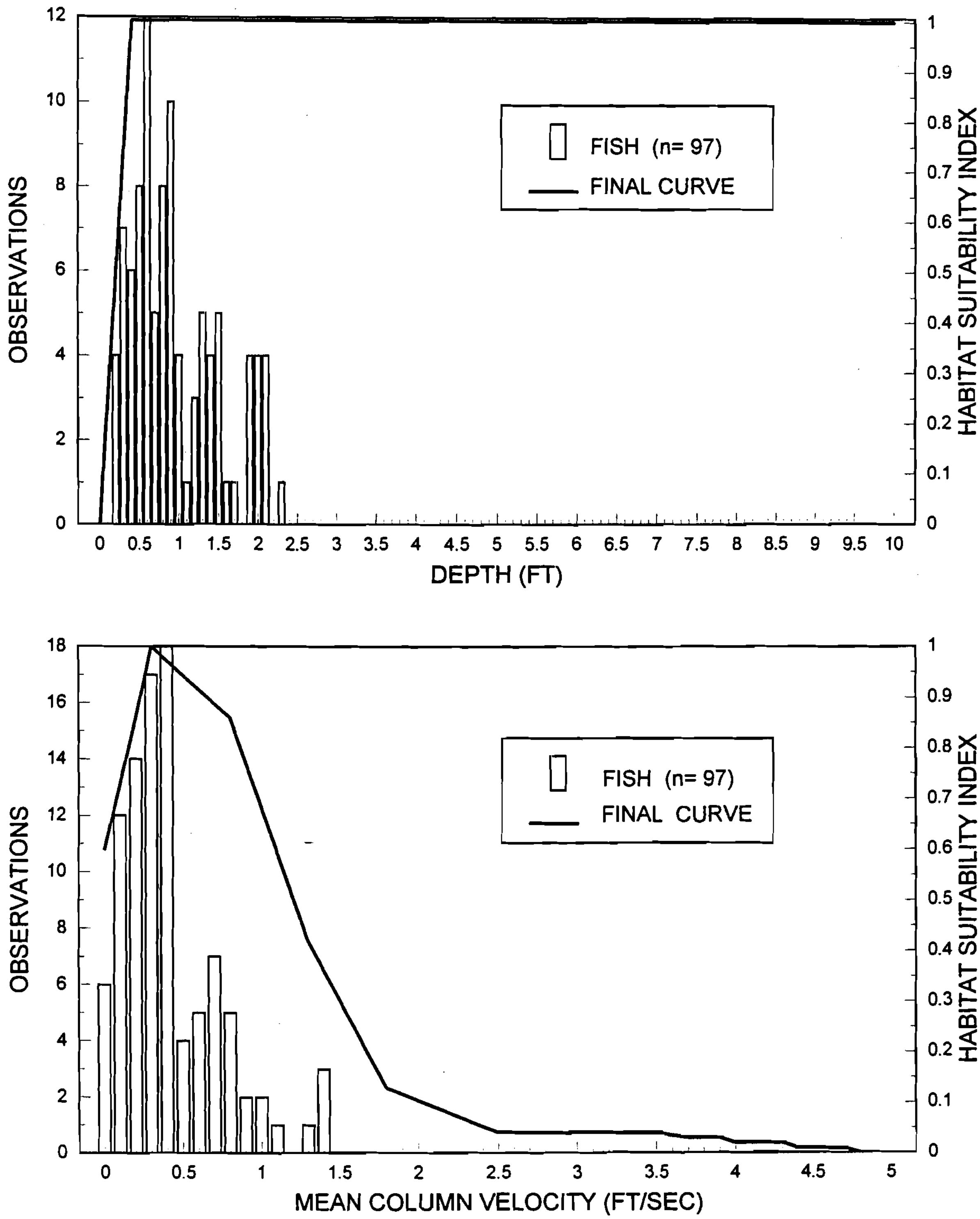


Figure 2.11 Steelhead juvenile overwintering observations and final water depth and velocity habitat suitability criteria, Trinity River, CA.

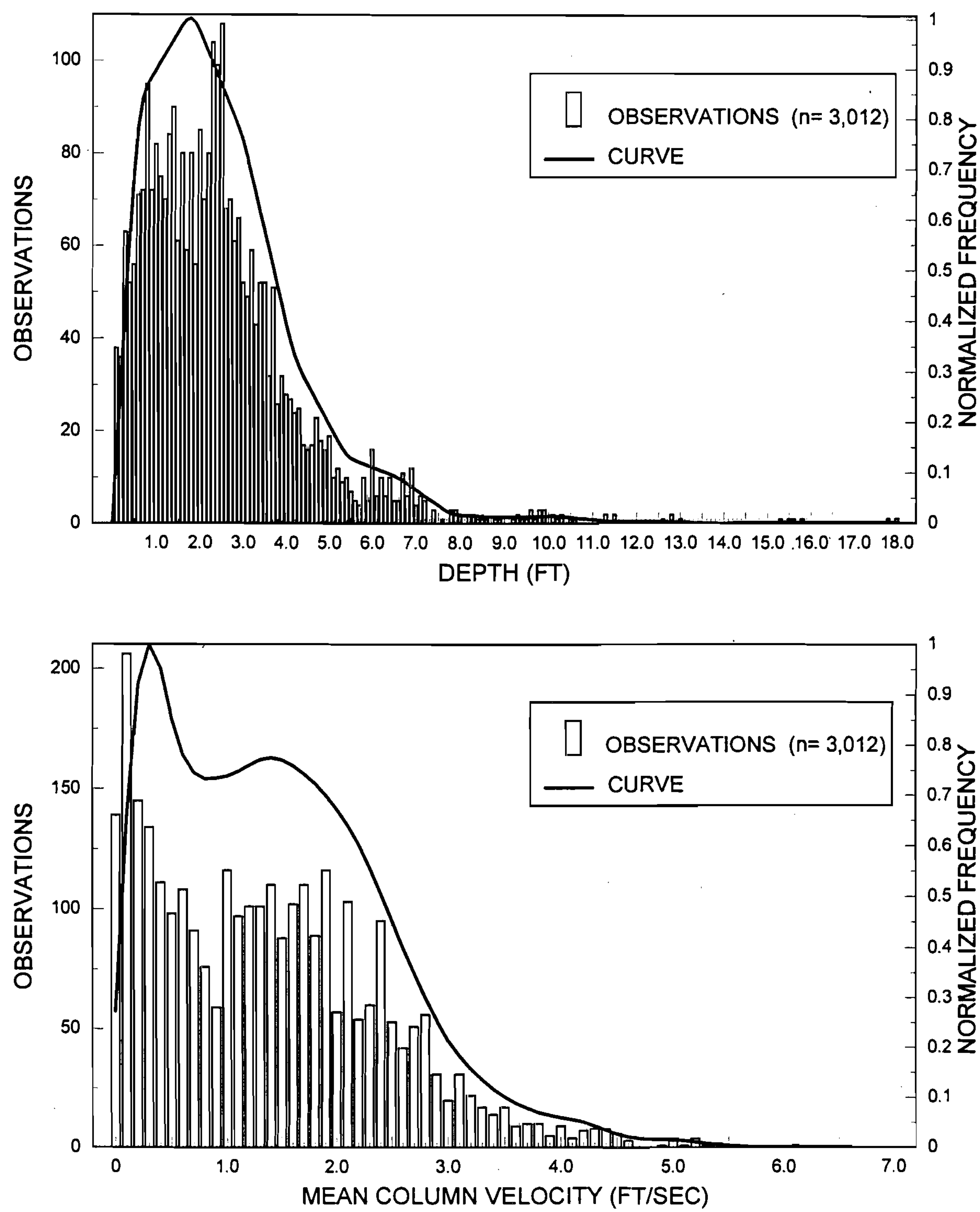


Figure 2.12 Availability simulations and water depth and velocity normalized frequency distributions, Trinity River, CA.

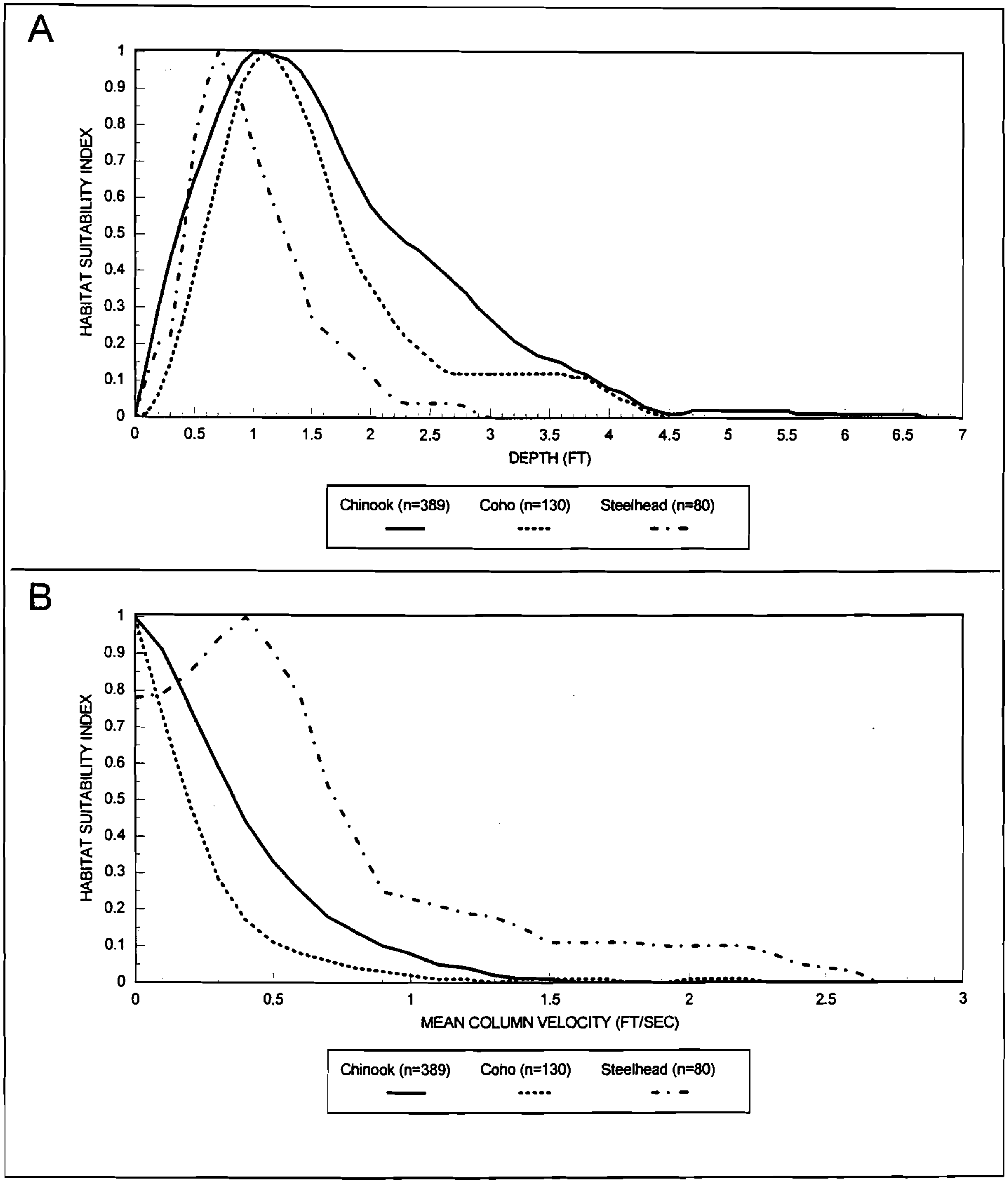


Figure 3.1 Depth (A) and velocity (B) habitat suitability criteria for chinook, coho, and steelhead fry habitat suitability criteria, Trinity River, CA, where (n) equals the number of observations.

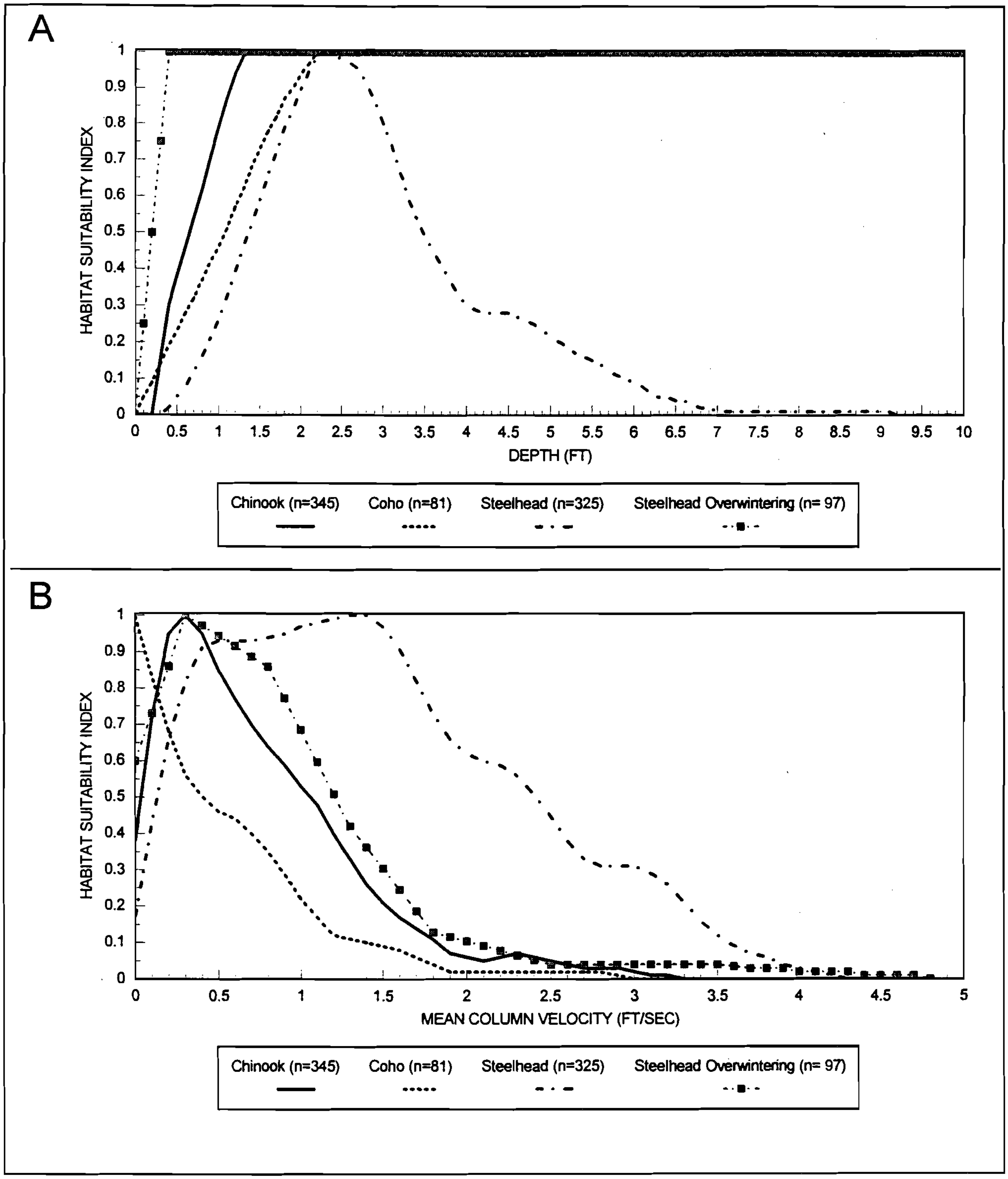


Figure 3.2 Depth (A) and velocity (B) habitat suitability criteria for chinook, coho, and steelhead juvenile habitat suitability criteria, Trinity River, CA, where (n) equals the number of observations.

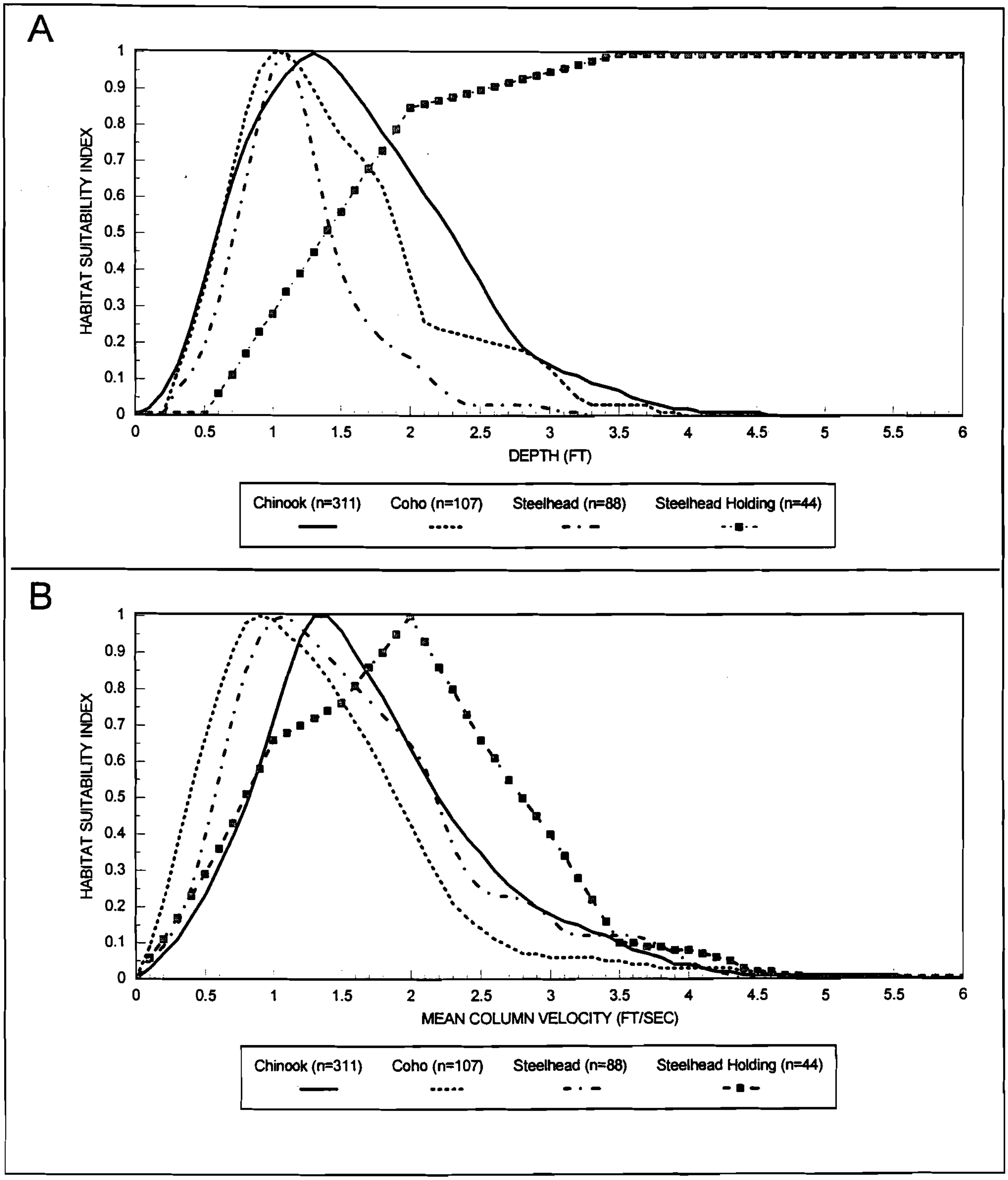


Figure 3.3 Depth (A) and velocity (B) habitat suitability criteria for chinook, coho, and steelhead spawning habitat suitability criteria, Trinity River, CA, where (n) equals the number of observations.

Table 2.1. Chinook Salmon Fry Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	1.00	0.00	0.00
0.10	0.91	0.20	0.30
0.20	0.75	0.50	0.64
0.30	0.59	0.60	0.74
0.40	0.44	0.70	0.83
0.50	0.33	0.80	0.91
0.60	0.25	1.20	1.00
0.70	0.18	1.30	0.99
0.80	0.14	1.50	0.95
0.90	0.10	1.70	0.84
1.00	0.08	1.80	0.77
1.10	0.05	1.90	0.70
1.20	0.03	2.40	0.48
1.30	0.02	2.70	0.40
1.40	0.01	2.80	0.37
1.50	0.01	2.90	0.34
1.60	0.00	3.00	0.30
100.00	0.00	3.10	0.27
		3.60	0.16
		3.70	0.15
		3.80	0.13
		3.90	0.12
		4.00	0.10
		4.10	0.08
		4.20	0.07
		4.30	0.05
		4.40	0.03
		4.50	0.02
		4.60	0.01
		4.70	0.01
		4.80	0.02
		6.60	0.01
		6.70	0.00

Table 2.2. Chinook Salmon Juvenile Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	0.38	0.00	0.00
0.10	0.72	0.10	0.07
0.20	0.95	0.20	0.15
0.30	1.00	0.30	0.22
0.40	0.95	0.40	0.30
0.50	0.85	0.50	0.38
0.60	0.77	0.60	0.46
0.70	0.70	0.70	0.54
0.80	0.64	0.80	0.62
0.90	0.59	0.90	0.70
1.00	0.53	1.00	0.79
1.10	0.47	1.10	0.87
1.20	0.40	1.20	0.94
1.30	0.33	1.30	0.98
1.40	0.26	1.40	1.00
1.50	0.21	100.00	1.00
1.60	0.17		
1.70	0.14		
1.80	0.11		
1.90	0.07		
2.00	0.07		
2.10	0.07		
2.20	0.07		
2.30	0.07		
2.40	0.06		
2.50	0.05		
2.60	0.04		
2.70	0.03		
2.80	0.03		
2.90	0.03		
3.20	0.01		
3.30	0.00		
100.00	0.00		

Table 2.3. Chinook Salmon Spawning Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	0.00	0.00	0.00
0.10	0.03	0.40	0.24
0.30	0.11	0.50	0.37
0.50	0.23	0.60	0.51
0.70	0.39	0.70	0.64
0.90	0.59	0.80	0.75
1.10	0.83	0.90	0.83
1.20	0.94	1.10	0.94
1.30	1.00	1.20	0.98
1.40	1.00	1.30	1.00
1.50	0.96	1.40	0.98
1.80	0.78	1.50	0.94
2.20	0.50	2.30	0.50
2.30	0.44	2.70	0.24
2.60	0.30	2.80	0.19
2.90	0.20	2.90	0.16
3.10	0.16	3.10	0.12
3.90	0.04	3.20	0.11
4.00	0.04	3.30	0.09
4.10	0.03	3.50	0.07
4.20	0.02	3.60	0.05
4.40	0.01	3.90	0.02
5.60	0.00	4.10	0.01
100.00	0.00	4.60	0.00
		100.00	0.00

Table 2.4. Coho Salmon Fry Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.
0.00	1.00
0.10	0.73
0.20	0.48
0.30	0.28
0.40	0.17
0.50	0.11
0.60	0.08
0.70	0.06
0.80	0.04
0.90	0.03
1.00	0.02
1.10	0.01
1.20	0.01
1.30	0.00
100.00	0.00

DEPTH	S.I.
0.00	0.00
0.10	0.01
0.20	0.06
0.30	0.15
0.40	0.26
0.50	0.39
0.60	0.53
0.70	0.66
0.80	0.79
0.90	0.91
1.00	0.97
1.10	1.00
1.20	0.98
1.30	0.93
1.40	0.86
1.50	0.78
1.60	0.68
1.70	0.57
1.80	0.48
1.90	0.41
2.00	0.36
2.10	0.31
2.20	0.26
2.30	0.22
2.40	0.19
3.70	0.11
3.80	0.11
3.90	0.09
4.00	0.07
4.10	0.05
4.20	0.04
4.30	0.02
4.50	0.00
100.00	0.00

Table 2.5. Coho Salmon Juvenile Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	1.00	0.00	0.00
0.10	0.83	0.10	0.05
0.20	0.68	0.20	0.09
0.30	0.56	0.30	0.14
0.40	0.50	0.40	0.19
0.50	0.46	0.50	0.23
0.60	0.44	0.60	0.28
0.70	0.40	0.70	0.32
0.80	0.35	0.80	0.37
0.90	0.29	0.90	0.42
1.00	0.22	1.00	0.46
1.10	0.17	1.10	0.51
1.20	0.12	1.20	0.57
1.30	0.11	1.30	0.62
1.40	0.10	1.40	0.68
1.50	0.09	1.50	0.73
1.60	0.08	1.60	0.78
1.70	0.06	1.70	0.82
1.80	0.04	1.80	0.87
1.90	0.02	1.90	0.90
2.80	0.02	2.00	0.94
2.90	0.01	2.10	0.97
3.00	0.00	2.20	1.00
100.00	0.00	100.00	1.00

Table 2.6. Coho Salmon Spawning Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	0.00	0.00	0.00
0.10	0.00	0.20	0.00
0.20	0.21	0.40	0.22
0.30	0.37	0.50	0.35
0.40	0.52	0.60	0.50
0.50	0.66	0.70	0.67
0.60	0.79	0.80	0.83
0.70	0.90	0.90	0.95
0.80	0.98	1.00	1.00
0.90	1.00	1.10	1.00
1.00	0.99	1.30	0.90
1.10	0.95	1.80	0.63
1.20	0.92	1.90	0.52
1.30	0.88	2.00	0.39
1.50	0.77	2.10	0.26
1.70	0.65	2.20	0.24
2.30	0.21	2.80	0.18
2.40	0.17	2.90	0.16
2.60	0.11	3.00	0.13
2.70	0.07	3.20	0.05
3.00	0.06	3.30	0.03
3.40	0.05	3.80	0.01
3.60	0.04	4.00	0.00
3.80	0.03	100.00	0.00
4.30	0.03		
4.40	0.02		
4.60	0.01		
4.80	0.00		
100.00	0.00		

Table 2.7. Steelhead Fry Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.
0.00	0.78
0.10	0.79
0.20	0.85
0.30	0.94
0.40	1.00
0.50	0.91
0.60	0.78
0.70	0.54
0.80	0.40
0.90	0.25
1.00	0.23
1.10	0.21
1.20	0.19
1.50	0.11
1.60	0.11
1.70	0.11
1.80	0.11
1.90	0.10
2.00	0.10
2.10	0.10
2.20	0.10
2.60	0.03
2.70	0.00
100.00	0.00

DEPTH	S.I.
0.00	0.00
0.10	0.11
0.20	0.20
0.30	0.22
0.40	0.46
0.50	0.76
0.60	0.91
0.70	1.00
0.80	0.92
0.90	0.86
1.00	0.74
1.10	0.65
1.20	0.56
1.30	0.47
1.40	0.40
1.50	0.27
1.60	0.24
1.70	0.21
1.80	0.18
1.90	0.15
2.00	0.12
2.10	0.08
2.20	0.05
2.30	0.04
3.00	0.00
100.00	0.00

Table 2.8. Steelhead Juvenile Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	0.17	0.00	0.00
0.10	0.43	0.30	0.00
0.20	0.66	0.40	0.02
0.30	0.82	0.60	0.08
0.40	0.91	0.80	0.16
0.50	0.93	1.00	0.26
0.70	0.93	1.10	0.32
0.80	0.94	1.30	0.46
0.90	0.95	1.40	0.52
1.00	0.97	2.00	0.90
1.30	1.00	2.20	0.99
1.40	1.00	2.30	1.00
1.50	0.97	2.40	0.99
1.60	0.91	2.60	0.97
1.80	0.73	2.70	0.95
1.90	0.66	2.90	0.86
2.00	0.62	3.40	0.54
2.30	0.56	3.90	0.33
2.40	0.51	4.00	0.30
2.60	0.38	4.20	0.28
2.70	0.33	4.50	0.28
2.80	0.31	4.80	0.25
3.00	0.31	4.90	0.23
3.20	0.26	5.40	0.16
3.40	0.16	6.10	0.08
3.60	0.09	6.20	0.06
3.70	0.07	6.40	0.05
3.90	0.04	7.00	0.04
4.30	0.00	7.10	0.03
100.00	0.00	7.20	0.02
		7.30	0.02
		7.40	0.01
		9.10	0.01
		9.20	0.00
		100.00	0.00

Table 2.9. Steelhead Spawning Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.	DEPTH	S.I.
0.00	0.00	0.00	0.00
0.30	0.15	0.30	0.07
0.50	0.39	0.40	0.11
0.60	0.55	0.50	0.19
0.70	0.72	0.60	0.31
0.80	0.85	0.70	0.47
0.90	0.94	0.80	0.64
1.00	0.99	0.90	0.82
1.10	1.00	1.00	0.96
2.00	0.65	1.10	1.00
2.10	0.59	1.20	0.90
2.20	0.48	1.30	0.72
2.30	0.37	1.40	0.54
2.40	0.29	1.50	0.40
2.50	0.25	1.60	0.31
2.60	0.23	1.70	0.25
2.70	0.23	1.80	0.21
2.80	0.22	1.90	0.18
2.90	0.20	2.00	0.16
3.00	0.17	2.10	0.12
3.10	0.13	2.20	0.08
3.20	0.12	2.30	0.05
3.70	0.11	2.40	0.03
3.90	0.07	2.90	0.03
4.10	0.03	3.00	0.02
4.40	0.00	3.10	0.01
100.00	0.00	3.20	0.01
		3.30	0.00
		100.00	0.00

Table 2.10. Steelhead Adult Holding Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.
0.00	0.00
0.60	0.36
1.00	0.66
1.50	0.76
1.60	0.81
2.00	1.00
2.50	0.66
3.00	0.40
3.10	0.34
3.20	0.23
3.30	0.22
3.50	0.10
3.60	0.10
3.70	0.09
3.80	0.09
3.90	0.08
4.00	0.08
4.30	0.05
4.40	0.03
4.50	0.02
4.60	0.02
4.70	0.01
4.80	0.01
4.90	0.00
100.00	0.00

DEPTH	S.I.
0.00	0.00
0.50	0.00
0.60	0.06
0.70	0.11
0.90	0.23
1.00	0.28
1.10	0.34
1.20	0.39
1.40	0.51
1.50	0.56
1.70	0.68
1.80	0.73
2.00	0.85
3.50	1.00
100.00	1.00

Table 2.11. Steelhead Juvenile Overwintering Velocity (ft/sec) and Depth (ft) Trinity River Utilization Criteria

VELOCITY	S.I.
0.00	0.60
0.30	1.00
0.80	0.86
1.30	0.42
1.80	0.13
2.50	0.04
3.80	0.04
4.00	0.03
4.70	0.03
5.30	0.00
100.00	0.00

DEPTH	S.I.
0.00	0.00
0.40	1.00
100.00	1.00

APPENDIX A

Plan of Study
For Trinity River
Fishery Flow Evaluations

Trinity River, Northwestern California

Lead Agency: U.S. Fish and Wildlife Service
Assisting Agencies: Members of the Trinity River Basin
Fish and Wildlife Task Force

Approved: /sgd/ Ronald E. Lambertson — DEC - 8 1983
Acting Director, U.S. Fish and Wildlife Service — Date

Study Goal: The goal of this study is to monitor the rehabilitation of fishery habitat in the Trinity River below Lewiston Dam in northwestern California. The information from this study together with harvest and escapement information from other ongoing studies will be used to advise the Secretary whether the Department is operating the Trinity River Division consistent with its authorizing provisions for the protection and propagation of fishery resources. This study will meet the intent of the Secretarial decision of January 1981 pertaining to increased flow releases for anadromous fishery protection in the Trinity River downstream of Lewiston Dam - a major feature of the Trinity River Division, Central Valley Project, operated by the U.S. Bureau of Reclamation.

Background and Overview: The Trinity River is a major tributary of the Klamath River in northwestern California. The natural resources of the Trinity River Basin sustain many important resource-based social and economic interests. Historically, the Trinity has been recognized as a major producer of chinook and coho salmon and steelhead trout. Indian, sport and commercial salmon fisheries have operated on these runs. Mineral, timber and water resources have also been developed in the Trinity Basin. These developments together with fisheries harvests are believed to have caused major declines in fall-run chinook and steelhead trout populations over the past two decades. Specific user groups dependent on the fisheries stocks as well as the general northern coastal economics have suffered as a result of the fisheries declines.

These losses are of high concern to this Department for two reasons: First, the Department has Indian Trust responsibilities which extend to protection of Indian fisheries rights and resources; and, second, the act authorizing the construction of the Trinity River Division of the Central Valley Project directs the Secretary to preserve and propagate anadromous fish in the basin.

The Trinity River Division which is the only major water development project in the Trinity River Basin serves to export water from the Trinity River to the Central Valley of California. Since its operation began in 1963, the project has annually exported about 75-90 percent of the runoff at Lewiston Dam. The remainder of flow has been released downstream either for fisheries purposes (about 10 percent annually 1963-73 and somewhat higher in more recent years) or as water surplus to the project's immediate needs.

Coincident with construction and operation of the Trinity River Division, logging accelerated within the Trinity Basin. Higher watershed erosion rates and lowered streamflows downstream of Lewiston Dam resulted in extensive sedimentation of fish habitat. Maintenance of minimum streamflow releases and construction and operation of a fish hatchery were not sufficient to sustain fisheries populations. Declines in some stocks have exceeded 90 percent of former levels.

In December of 1980, the Fish and Wildlife Service and the Bureau of Reclamation reached an agreement to increase releases to the Trinity

River below Lewiston Dam to aid in the rehabilitation of the important and rapidly dwindling anadromous fishery resources. The agreement was approved by the former Secretary Andrus in January 1981 and has been supported by Secretary Watt.

In addition to increasing flow releases for fishery purposes, the agreement also provides for a special study over a 12-year period during which improved releases would be maintained. The Fish and Wildlife Service is to conduct the study in consultation with the Bureau of Reclamation and the California Department of Fish and Game. At the end of the 12-year period, a report will be made to the Secretary describing the effectiveness of the improved flows and any other habitat rehabilitation measures (such as those contained in the proposed Trinity River Basin Fish and Wildlife Management Program) in restoring fishery populations and habitat below Lewiston Dam.

The fishery flow agreement and study are necessary because the congressional authorization for construction and operation of the Trinity River Division provides for the preservation and propagation of the Trinity's indigenous fishery resources by the Secretary and, as previously indicated, these resources are declining.

A number of factors, in combination, including overharvest, are thought to be responsible for fishery declines, but not all are within the jurisdiction of the Secretary of the Interior to correct. Habitat losses due to low riverflows and sediment accumulation in the main stem Trinity River can be restored in part by increasing flows, trapping sediments, and mechanically rehabilitating spawning and rearing areas, and by reducing erosion through improved watershed management in tributary streams. The Department of the Interior is focusing effort on these tasks.

The Secretary has taken the first step towards rehabilitation of fish runs by improving fishery flow releases (at the expense of other project water uses). A sediment control project (Buckhorn Mtn. Dam-Grass Valley Creek Sediment Control Project) has been authorized by Congress and Interior will likely begin work on the project during Fiscal Year 1984. The Trinity River Basin Fish and Wildlife Task Force--a 13-member group of Government specialists advisory to the Bureau of Reclamation--has developed a comprehensive plan for the rehabilitation and management of fish and wildlife resources throughout the Trinity Basin. With the cooperative assistance of the Bureau of Reclamation and Bureau of Indian Affairs, Fish and Wildlife Service is preparing an Environmental Impact Statement on the Task Force management program. Legislation to authorize and fund the program has been introduced in Congress.

The efforts described above will largely rehabilitate salmon and steelhead habitat in the Trinity River system. Restoration of the fish populations themselves, however, will also be dependent on effective harvest management. This year (1983) the Pacific Fisheries Management Council has adopted a 20-year plan to rebuild salmon runs in the Klamath-Trinity Basin through controlled ocean harvests. Adherence to that plan or even tougher standards, as well as the effective management of Indian and sport fisheries, is vital to the successful replenishment of the anadromous runs.

Although the 12-year study plan presented here addresses habitat restoration, it is clear that consideration will have to be given to the role of harvest management in allowing run goals to be met. It is anticipated that relevant data and evaluations from other monitoring efforts (harvests and escapements) will be considered and included in developing reports and recommendations to the Secretary during this study.

Study Description: The study will span 12 years and consist of 6 major tasks:

1. Study plan review and modification
2. Habitat preference criteria development
3. Habitat availability and need
4. Fish population characteristics and life history relationships
5. Study coordination
6. Reports

The study will require a maximum of 8.8 full-time-equivalent positions depending on work in progress and will require annual funding ranging from $116,431 to $359,273. The study will focus on the main stem Trinity River from Lewsiton Dam to its confluence with the Klamath River at Weitchpec. Each study task is described in the following section. Efforts and funding estimates for each task are presented. Effort is shown in biologist days and total staff days (A biologist-day includes biotechnicians). It is assumed that the Fish and Wildlife Service will be the lead agency. There is opportunity for (and interest in) participation by the California Department of Fish and Game and Water Resources and Hoopa Valley Business Council. Their cooperation will be solicited. Interagency participation may alter effort and funding requirements somewhat.

A matrix table showing task schedules and levels of effort throughout the study period is appended. It is intended that this study: 1) Be conducted by utilizing current scientific methodologies; 2) be flexible to meet changing fishery resource conditions; 3) be closely coordinated with other studies and resource management agencies; and 4) be reported on, by performing timely data analyses, at regular intervals and at the conclusion of the study.

Consequences of Not Performing Study: Without this study the Department of the Interior will be unable to show how it is meeting its commitments and requirements to maintain and propogate fishery resources in the Trinity River Basin. The Department will continue to be challenged by Indian and other fishery resource management and interest groups and the Trinity River Division will continue to be viewed by these elements as a classic example of the incompatibility of water resource development with fishery maintenance and of the failure of the Federal Government to be responsive to area of origin concerns.

TASK 1. Annual Study Plan Review and Modification

Objective: The objective of TASK 1 is to assure that the study plan reflects current findings and data needs.

Need: As the study progresses certain study elements may require an approach modified from that originally envisioned. Changes will be made based on experience gained from previous efforts.

Methods: Each study year the project leader will review the study efforts and findings with the principal resource management agencies in the Trinity River Basin, including the Trinity River Basin Fish and Wildlife Task Force. Based on these meetings a final study plan for the following year will be prepared.

Effort: Work required to complete TASK 1 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1-11	55 (5/yr)	110 (10/yr)
12	0	0
Total	55 days	110 days

Funding: Funding required to complete TASK 1 is estimated to be:

Study Year(s)	Amount
1	$ 1,590
2-11	16,630 ($1,663/yr)
12	0
Total	$18,223

TASK 2. Habitat Preference Criteria Development

Objective: The objective of Task 2 is to develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for chinook and coho salmon and steelhead trout spawning, incubation, rearing, holding, and migration. Other factors such as water quality and temperature will also be considered under TASK 3.

Need: Improved preference criteria are needed to use with streamflow hydraulic data to determine the amount of habitat presently existing for salmon and steelhead, to determine the amount required and types required to achieve target levels of natural fish production, and to monitor increases in habitat gained from flow management and mechanical habitat rehabilitation work.

Methods: Field data will be collected using a variety of techniques. Emphasis will be on visual observations through diving and snorkeling where possible. Other techniques may include electrofishing, seining, redd sampling, and other measures as necessary. Where sufficient data are available, a bivariate analysis will be performed using procedures outlined in Instream Flow Information Paper No. 12 (Bovee, FWS/OBS 82/26, 1982) to develop habitat preference criteria for the following species and life stages:

Species	Race	Life Stage
Chinook salmon	Spring run	Adult holding Spawning Incubation Rearing (fry) Juvenile migration
Chinook salmon	Fall run	Adult holding Spawning Incubation Rearing (fry) Juvenile migration
Coho salmon	Fall run	Adult holding Spawning Rearing (fry) Rearing (yearling) Juvenile migration

Steelhead trout	Summer run (possible)	Adult holding Spawning Rearing (fry) Rearing (yearling) Juvenile migration
Steelhead trout	Winter run	Adult holding Spawning Incubation Rearing (fry) Rearing (yearling) Juvenile migration

Effort: Effort needed to complete TASK 2 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	178	356
2	200	400
3	145	290
4-11	88 (11/yr)	176 (22/yr)
12	0	0
Total	611	1,222

Funding: Funding required to complete TASK 2 is estimated to be:

Study Year(s)	Amount
1	$ 56,604
2	66,532
3	48,236
4-11	29,272 ($3,659/yr)
12	0
Total	$200,646

TASK 3. Determination of Habitat Availability and Needs.

Objectives: There are two objectives for TASK 3. The first is to determine the amount of salmon and steelhead habitat available in the Trinity River downstream of Lewiston Dam under various flow conditions and the various levels of habitat rehabilitation that may be achieved either through the Trinity River Basin Fish and Wildlife Management Program or through other resource management actions. The second objective is to determine the amount of habitat required for each freshwater life stage of salmon and steelhead to sustain those portions of the fish populations in the Trinity Basin that were historically dependent on the Trinity River downstream of Lewiston Dam.

Need: The information from this TASK is needed to evaluate the effectiveness of riverflows and other measures in providing adequate amounts and distribution of fish habitat.

Methods: The Incremental Instream Flow Methodology developed by the Fish and Wildlife Service will be utilized as the primary evaluation tool. The methodology and its uses are described in Instream Flow Information Paper No. 12 (Bovee, FWS/OBS 82/26, 1982) and other publications by the Service's Instream Flow and Aquatic Systems Group. The methodology uses hydraulic and biological data to simulate habitat conditions over a range of potential flows. Water temperatures and other water quality data will be collected and incorporated into the habitat evaluations.

Field data will be collected 3 to 4 times over the 12-year study period from representative study reaches between Lewiston and Weitchpec. This will allow a running tally of habitat conditions and make it possible to account for habitat changes due to flows and watershed restoration, as opposed to any instream habitat rehabilitation by mechanical means.

Calculations of available habitat will be based on habitat preference criteria developed under TASK 2. Determination of habitat eds will also consider population use data to be developed under TASK 4. Minor field and laboratory research investigations may be required to test the validity of assumptions on egg and fry survival under various sediment conditions. It is anticipated that this and other specialized work may be undertaken through cooperative arrangements with research institutions.

The major subtasks of TASK 3 are:

1. Selection, establishment and maintenance (minor brush clearing, surveying, etc.) of measurement stations.

2. Hydraulic data collection over a range of flows at each station--repeated 2-3 times after initial period depending on streamflows and channel conditions (rehabilitation work).

3. Data analysis and habitat projections assuming various channel and flow conditions, and temperature and other water quality conditions.

The field schedule and effort for each subtask is detailed in the appended table.

Effort: Work required to complete TASK 3 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	444	$ 888
2	390	780
4, 6, 8, 10	1,200 (300/yr)	2,400 (600/yr)
3, 5, 7, 9, 11	1,000 (200/yr)	2,000 (400/yr)
12	0	0
Total	3,034	$6,068

Funding: Funding required to complete TASK 3 is estimated to be:

Study Year(s)	Amount
1	$ 141,192
2	129,737
4, 6, 8, 10	399,192 ($99,798/yr)
3, 5, 7, 9, 11	332,660 ($66,532/yr)
12	
Total	$1,002,781

TASK 4. Determination of Fish Population Characteristics and Life History Relationships.

Objective: The objective of TASK 4 is to determine the relative levels of successful use by fish populations of available habitat in the Trinity River downstream of Lewiston Dam.

Need: Although some information is available on spawning escapements and spawning redd numbers in certain areas, very little is known about the total distribution of fish between Lewiston and Weitchpec or their spawning success and the subsequent survival and growth of juveniles. This type of information is needed to determine which habitat factors may be limiting the restoration of fish populations.

Methods: Selected study reaches will be surveyed periodically to develop indices of habitat use, fish distribution, and the survival and growth of juveniles. Survey field methods will include snorkeling, seining, electroshocking, emergent fry trapping, and other techniques found suitable. Survey methods will be refined and standardized based on experimentation during the first year.

Benthic aquatic organisms will also be monitored to determine the overall health and productive capabilities of the Trinity in the established field study reaches. Food habits of juvenile salmonids will be examined to determine utilization of available food supply. Methods for this study element will be patterned after those developed by researchers with the U.S. Forest Service and Brigham Young University (Biotic Condition Index: Integrated Biological, Physical and Chemical Stream Parameters for Management. Robert N. Winget and Fred A. Mangum. October 1979. Intermountain Region, Forest Service, U.S. Dept. of Agriculture) and others.

Effort: The effort required to complete TASK 4 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	93	186
2,4,6,8,10,11	2,232 (372/yr)	4,464 (744/yr)
3,5,7,9	3,736 (684/yr)	7,472 (1,368/yr)
12	0	0
Total	6,061	12,122

Funding: Funding required to complete TASK 4 is estimated to be:

Study Year(s)	Amount
1	$ 29,574
2,4,6,8,10,11	742,500 ($123,750/yr)
3,5,7,9	910,158 ($227,539/yr)
12	0
Total	$1,682,230

TASK 5. Study Coordination

Objective: The objective of TASK 5 is to develop and maintain coordination with other study and resource management agencies in the Trinity River Basin to maximize effective use of available information (and to avoid duplication of work).

Need: Presently, the California Department of Fish and Game, Bureau of Indian Affairs, Forest Service, Bureau of Land Management, Hoopa Valley Business Council (Fisheries Department) and the Fish and Wildlife Service have fisheries studies and management programs underway. Additional study efforts will occur under this program and the comprehensive fish and wildlife management program proposed by the Trinity River Basin Fish and Wildlife Task Force. It is essential that studies be coordinated to prevent unintended interference and to make use of study results in planning future work and making management decisions.

Methods: Coordination will be maintained through both formal and informal contacts. Other study leaders and local fishery resource managers will be contacted on at least a bimonthly basis. Formal coordination meetings will be scheduled twice yearly. Quarterly work progress reports (prepared under TASK 6) and preliminary fisheries reports will be provided to interested agencies.

Effort: The effort required to complete TASK 5 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1-11	220 (20/yr)	440 (40/yr)
12	10	20
Total	230	460

Funding: Funding required to complete TASK 5 is estimated to be:

Study Year(s)	Amount
1	$ 6,360
2-11	66,532 ($6,653/yr)
12	3,327
Total	$76,219

TASK 6. Reports (Progress, Findings and Recommendations)

Objective: The objectives of TASK 6 are: 1) To report on the analysis of information developed from field investigations (TASK 2, 3, and 4) and on relevant information from other studies which have a bearing on the levels of fishery resource rehabilitation achieved in the Trinity River between Lewiston and Weitchpec; and 2) to develop recommendations to the Secretary and to other resource management agencies concerning future management options and needs.

Need: Fishery rehabilitation efforts achieved through improved flow releases from Lewiston Dam and from mechanical aquatic habitat and watershed rehabilitation should be monitored and critically analyzed.

Methods: Three types of reports will be prepared under TASK 6. The first type will be quarterly progress and planning reports detailing study activities and accomplishments during the past quarter and describing anticipated activities during the current quarter. These will generally be prepared and distributed within 2 weeks of the close of each quarter. The second type will be preliminary findings reports containing field data and analyses for major portions of one or more study elements. As an example, this type of report would be produced following completion of the habitat preference criteria study element (TASK 2) and at the end of each of the 3 to 4 periods of hydraulic streamflow data collection and computer analysis (TASK 3). The preliminary findings reports should be completed after data analysis and during the year following completion of field work. The final type of report will be the concluding report to the Secretary.

The concluding report will summarize the findings of each of the study elements (from various preliminary findings reports), evaluate the results of improved flows and other rehabilitation measures in an overall manner, and convey to the Secretary the Service's recommendations with respect to future management options and needs for the Trinity River downstream of Lewiston Dam.

Effort: Effort needed to complete TASK 6 is estimated to be:

Study Year(s)	Biologist Days	Total Staff Days
1	10	20
2	20	40
4,6,8,10	120 (30/yr)	240 (60/yr)
3,5,7,9,11	130 (26/yr)	260 (52/yr)
12	340	680
Total	620	1,240

Funding: Funding required to complete TASK 6 is estimated to be:

Study Year(s)	Amount
1	$ 3,180
2	6,653
4,6,8,10	39,921 ($9,980/yr)
3,5,7,9,11	43,246 ($8,649/yr)
12	113,104
Total	$206,104

Schedule of Activities and Effort (Biologist Days) for Trinity River Fishery Flow Evaluations

Fiscal Year Study year	85 1	86 2	87 3	88 4	89 5	90 6	91 7	92 8	93 9	94 10	95 11	96 12
STUDY TASK												
Study Plan Review and Modification	5	5	5	5	5	5	5	5	5	5	5	
Habitat Preference Criteria Development	178	200	145	11	11	11	11	11	11	11	11	
Habitat Availability and Need	444	390	200	300	200	300	200	300	200	300	200	
Fish Population Characteristics and Relationships	93	372	684	372	684	372	684	372	684	372	372	
Study Coordination	20	20	20	20	20	20	20	20	20	20	20	10
Reports	10	20	26	30	26	30	26	30	26	30	26	340
Total Effort[a]	750	1,007	1,080	738	946	738	946	738	946	738	634	350
Funding	238,500	335,000	359,273	245,503	314,696	245,503	314,696	245,503	314,696	245,503	210,906	116,431
Grand Total Cost	< $3,186,210 >											

[a]Effort in Biologist Days. 1 Biologist Day = 2 Staff Days

APPENDIX B

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION STUDY

1985

U.S. Fish and Wildlife Service
Division of Ecological Services
Sacramento Field Office
Sacramento, California

Prepared by:

Michael E. Aceituno (Project Leader)
Fish and Wildlife Biologist

Andy Hamilton
Fish and Wildlife Biologist

Mark Hampton
Fish and Wildlife Biologist

Randy Brown
Fishery Biologist

January 1985

DESCRIPTION OF STUDY REACHES

In order to complete study tasks in an organized manner, the mainstem of the Trinity River between Lewiston Dam and Weitchpec (approximately 110 river miles) was partitioned into three general segments: upper, middle, and lower. Each of these broad segments has distinctive features and is used to different degrees by salmon and steelhead. The three segments are: I) Lewiston Dam to North Fork Trinity River; II) North Fork Trinity River to South Fork Trinity River; and III) South Fork Trinity River to the confluence with the Klamath River (Weitchpec).

The upper segment (Lewiston Dam to N.F. Trinity) is probably the most important to salmonid production. The majority of the substrate within this segment is composed of sand, gravel, and cobbles with less bedrock than further downstream. Controlled river flows and encroachment of riparian vegetation are characteristic of this segment. The river itself has largely become constricted into long uniform runs with swift flows.

The character of the river within the middle segment (North Fork to South Fork) is quite varied. Although the overall gradient is moderate within this segment it includes the precipitous gorge between China Slide and Gray Falls, the most rugged section of the Trinity River. Here, the river is controlled primarily by a bedrock channel and is characterized by long, moderately deep pools, numerous sandy beaches, and steep wooded hillsides. The river corridor is relatively undeveloped except for a few scattered residences and small communities.

The lower segment extends 30.8 miles from the South Fork to the confluence with the Klamath River (at Weitchpec). Generally the river gradient is low as the river passes northward through a v-shaped valley, into the settled area around Willow Creek, through a short gorge above Tish-Tang, the Hoopa Valley and finally a narrow gorge before entering the Klamath River. In the valley reaches the river meanders across large gravel and cobble bars which are mostly clear of vegetation. The river flow has been greatly increased due to inflow from the South Fork, broadening and flattening the channel somewhat with numerous gravel deposits and few rapids.

Within these three generalized river segments, 14 representative study reaches were selected: nine in the upper river segment; two in the middle segment; and three in one lower segment (Table 1 and Figure 3).

Table 1. Representative Study Reaches, Trinity River Flow Evaluation Study, 1985. (See also Figure 3 for locations).

	River Segment	Study Reach	Description	No. IFIM Transects
I.	Upper	1. Lewiston Dam	Lewiston Dam to Old Fish Weir	19
		2. Cemetery	Old Fish Weir to mouth of Rush Creek	13
		3. Bucktail	Mouth of Rush Creek to mouth of Grass Valley Creek	11
		4. Poker Bar	Mouth of Grass Valley Creek to Limekiln Gulch	10
		5. Steel Bridge	Limekiln Gulch to the mouth of Indian Creek	12
		6. Indian Creek	Mouth of Indian Creek to Douglas City	0
		7. Steiner Flat	Douglas City to Dutch Creek	10
		8. Oregon Gulch	Dutch Creek to Canyon Creek	9
		9. Junction City	Canyon Creek to North Fork Trinity	9
II.	Middle	10. Del Loma	North Fork Trinity to Cedar Flat	11
		11. Hawkins Bar	Cedar Flat to South Fork Trinity	8
III.	Lower	12. Camp Kimtu	South Fork Trinity to the mouth of Horse Linto Creek	0
		13. Tish Tang	Mouth of Horse Linto to Hoopa Valley	9
		14. Hoopa Valley	Hoopa Valley	6

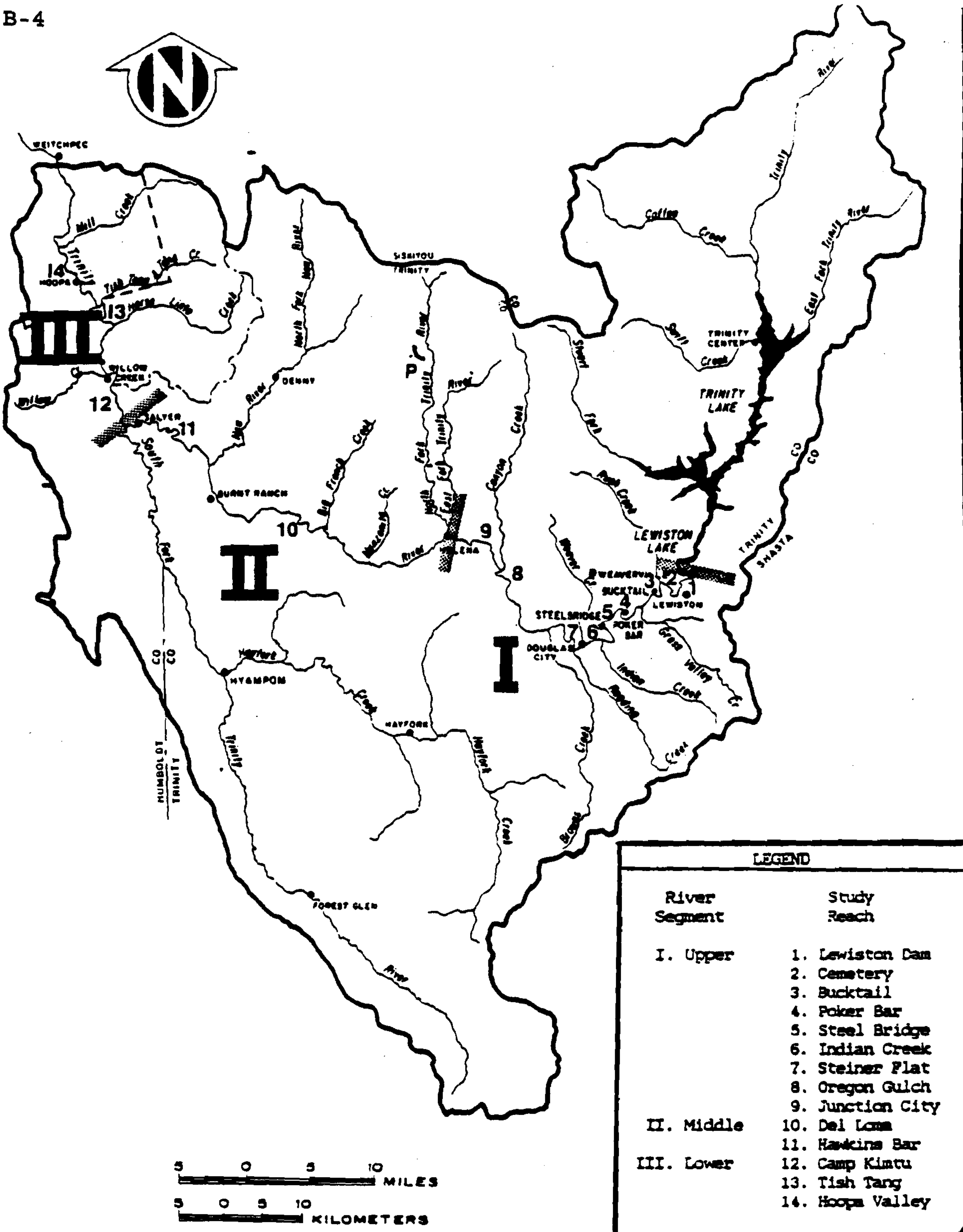


Figure 3. Map of the Trinity River Flow Evaluation Study Area.

HABITAT PREFERENCE CRITERIA DEVELOPMENT

(TASK 2)

Collection of habitat preference data began in January 1985. A total of 1470 observations have been made using snorkel techniques. An additional 4 observations were made with a seine on the lower two study sites (13 & 14) when zero visibility prevented effective snorkel methods from being used. Of the 1470 total observations, 647 were composed of random habitat observations. A summary of the number of observations taken to date by study reach for each species and life stage is presented in Table 2.

Table 2. Number of microhabitat observations by study reach, Trinity River Flow Evaluation Study.

Fish Observations

Study Reach	Chinook Salmon	Coho Salmon	Steelhead Trout	Rainbow Trout	Brown Trout	Available Habitat Observations
Lewiston Dam	35	80	27	8	4	185
Cemetery	104	43	2	34	43	113
Bucktail	27	1	22	0	24	149
Poker Bar	49	1	1	17	6	150
Steelbridge	40	5	0	18	5	150
Indian Creek	58	0	3	23	12	150
Steiner Flat	14	3	3	21	2	140
Oregon Gulch	10	0	14	0	0	50
Junction City	23	1	13	11	0	33
Del Loma	10	4	2	10	4	31
Hawkins Bar	0	0	0	0	0	0
Camp Kimtu	0	0	0	0	0	0
Tish Tang	13	2	0	16	0	19
Hoopa Valley	0	0	0	0	0	0
TOTALS	383	140	87	158	100	1170

A frequency distribution of sites sampled indicates a skewed distribution, with the upper river sites being sampled more than the lower river sites. This is because of two factors: 1) river visibility decreases downstream, and 2) the proximity of the office. More effort will be directed to increased sampling of lower river sites during 1986.

At this point in time there has been no effort made to analyse the field data. A preliminary report of findings will be prepared in 1986.

APPENDIX C

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION STUDY

1986

U.S. Fish and Wildlife Service
Division of Ecological Services
Sacramento Field Office
2800 Cottage Way, Rm. E-1803
Sacramento, California 95825

by

Michael E. Aceituno

Andrew Hamilton

Mark Hampton

and

William Somer

December 1986

HABITAT PREFERENCE CRITERIA DEVELOPMENT (TASK 2)

The objective of task 2 is to develop habitat preference criteria quantifying depths, velocities, substrates, and cover requirements for each lifestage and species of anadromous salmonids in the Trinity River. The resulting habitat preference curves will be used in conjunction with hydraulic streamflow data to determine the amount of habitat available for salmon and trout at various streamflows as well as determine the amount of habitat required to reach target levels of natural fish production. Data collection is planned over a 3-year period, which began in January of 1985. Following is a preliminary report of findings after almost two years of data collection ending on October 31, 1986.

Preliminary Habitat Utilization Curve Development

Methods

Habitat use data is being collected for all lifestages of chinook and coho salmon, steelhead/rainbow trout, and brown trout. Data collection has been accomplished through both direct and indirect sampling methods. Direct observations are made either by mask and snorkel, from the bank, or from a raft during float trips. When poor water clarity prevents effective use of direct observation methods, indirect sampling with either a backpack electrofisher or seine is used.

Sampling is conducted within fourteen study sites located on the Trinity River between Lewiston Dam and Weitchpec (Figure 2).

Direct observations with a mask and snorkel requires two persons, one as the snorkel observer and one support person to record data, operate the flow meter, and control the raft. Sampling is conducted in a downstream direction at each study site. Sampling in an upstream direction proved to be impossible due to the size of the river and high water velocities. The observer works in a zig-zag pattern across the river channel from bank to bank. At each bank sampling in an upstream direction for short distances is done when water velocities permit. This sampling technique allows for nearly complete coverage of the study site. When fish are spotted the observer determines the species, lifestage, behavior, and focal point. The support person is then signaled to approach and the observation is completed. When fish are spotted in the thalweg, where water is to deep or swift to stand, the observer floats motionless past the fish until out of sight. The observer then carefully approaches the fish from the rear or side. Once the observer has determined that the fish is not startled by his presence the observation is made. No observations are conducted on fish believed to be startled or

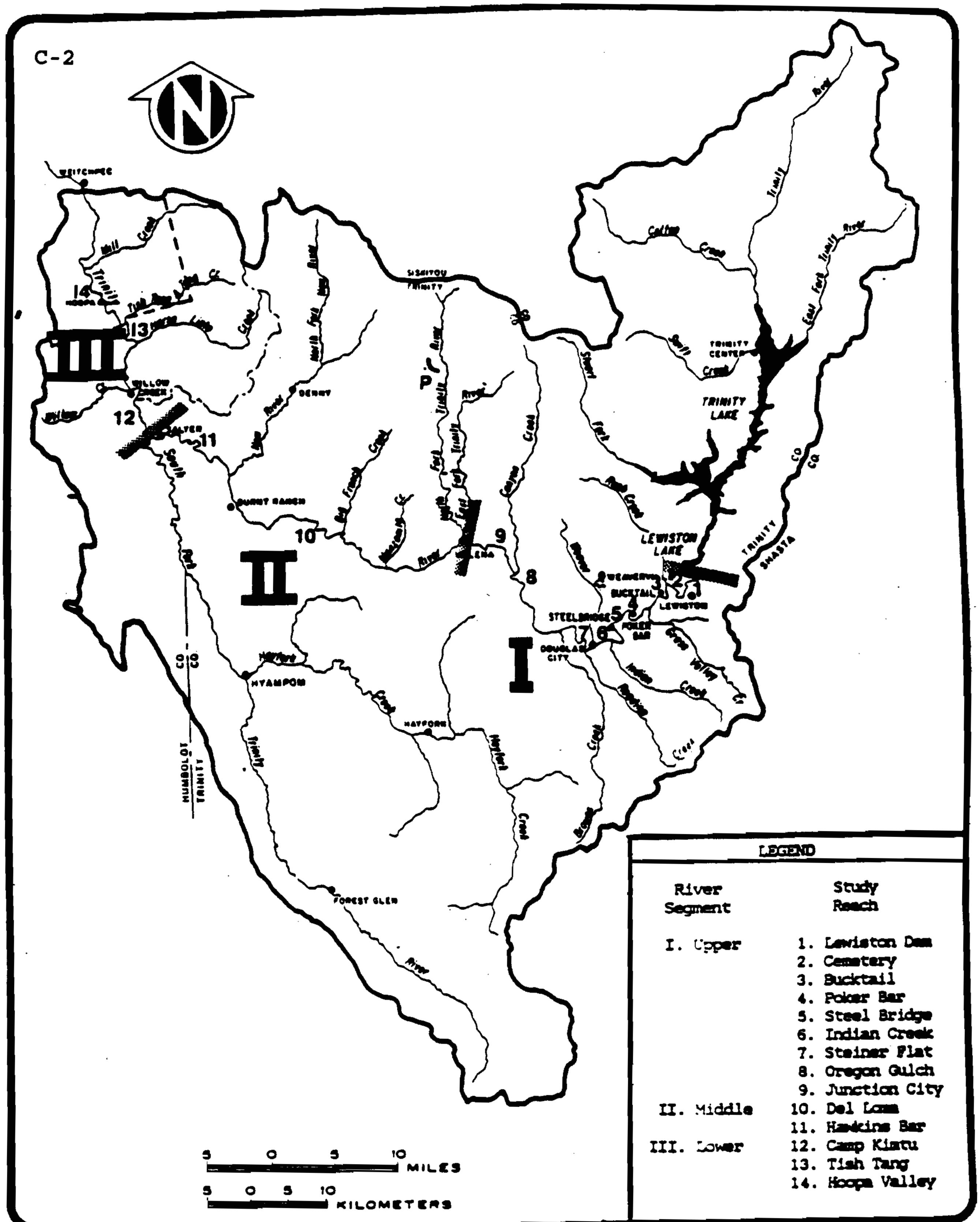


Figure 2. Map of the Trinity River Flow Evaluation Study Area

disturbed by the observer. When schools of juvenile salmon are encountered, the number of fish in the school is counted or estimated and the observation is made at the focal point of the school. When one school of fish is found to occupy more than one microhabitat, additional observations are made in order to accurately represent those microhabitats used. Habitat use measurements of spawning salmon and steelhead trout are taken 0.5 feet upstream of the redd, along the centerline, in an attempt to simulate prespawning hydraulic and substrate conditions. Fish nose velocities are taken at 0.4 feet from the bottom for all spawning observations.

For indirect observations both a backpack electrofisher and bag seine are used. Selected areas within each study site are sampled in an upstream direction with the electrofisher. When fish are sampled the species and lifestage are noted and a marker is placed designating the capture location. Once sampling is completed we go back to the first marker placed and systematically work upstream recording each observation. The area sampled is then measured and habitat availability measurements are taken at 0.25, 0.50, and 0.75 of the length and at 0.25, 0.50, and 0.75 in width, at each of the length intervals for a total of nine observations.

Seining is done in a downstream direction over monotypic habitat types, such as gravel bars or backwaters. All fish captured are recorded for species, length, and lifestage. The area of the seine haul is then measured and representative habitat measurements are made using the same method for obtaining the habitat availability measurements described above.

Data Requirements

Fourteen habitat parameters are recorded for each observation taken when using direct observation field techniques. The species and lifestage are determined. Fish less than 50 mm in forklength are considered fry. Fish greater than or equal to 50 mm and less than or equal to 200 mm are considered juveniles, and fish greater than 200 mm were considered adults. An estimate of forklength is obtained with the help of an underwater slate which has a centimeter scale marked on it. When more than one fish is utilizing the microhabitat focal point, as is often the case with schools of juvenile chinook salmon, the total number of fish is counted or estimated. The behavior of the fish being observed is categorized as either holding, roving, feeding or spawning. The total depth and depth of fish are both measured as the distance up off of the bottom in feet. The depth of fish is measured as the distance from the bottom to the focal point of an individual fish or school of fish. Two water velocities are taken at each observation, a mean column water velocity and a fish nose water velocity. Mean column water velocity is measured at 0.6 depth from the water surface for water less than 2.5 feet deep; and the average of the velocities measured at 0.2 depth and 0.8 depth from the surface for water greater than or equal to 2.5 feet deep. Water velocities are measured with either a Marsh McBirney model

201 flow meter or a Price "AA" current meter.

A three-digit code is used to describe the cover types and quality of the cover being used by the observed fish (Table 1). The first digit in code describes the dominate cover type present while the second digit describes the subdominant cover type, if present. The third code value, which follows a decimal, describes the quality of the cover types present as either poor, moderate, good, or excellent.

Table 1. Cover code descriptions used to develop habitat utilization criteria for the Trinity River Flow Evaluation, Trinity Co., California, 1986.

Code	Cover Type	Description
0	No cover	gravel less than 2 inches or any larger material which is embedded to the extent that no cover is available.
1	Cobble	75 - 300mm and larger, clear of fines.
2	Boulders	300mm and larger, clear of fines.
3	Small woody debris	brush and limbs less than 9 inches in diameter.
4	Large woody debris	logs and rootwads greater than 9 inches in diameter.
5	Undercut bank	undercut at least 0.5 feet.
6	Overhanging vegetation	within 1.5 feet of the water surface
7	Aquatic vegetation	

recorded as DS.Q where D = Dominant cover type
S = Subdominant cover type
Q = Quality of cover

The substrate compositions which are utilized or found present under observed fish are described with use of the Brusven sustrate index (Bovee 1982). The Brusven index is composed of a 3 digit descriptor of dominant substrate, subdominant substrate and percent embedded in fines (DS.%E).

We expanded the Brusven index to include bedrock as one of the possible substrate types present (Table 2).

Table 2. Expanded Brusven substrate index used for habitat utilization criteria development, Trinity River Flow Evaluation, Trinity Co., California, 1986.

Code	Substrate type	Size Range (mm)
0	Fines	< 4 mm
1	Small Gravel	4 - 25mm
2	Medium Gravel	25 - 50mm
3	Large Gravel	50 - 75mm
4	Small Cobble	75 -150mm
5	Medium Cobble	150 -225mm
6	Large Cobble	225 -300mm
7	Small Boulder	300 -600mm
8	Large Boulder	> 600mm
9	Bedrock	

(DS.%) Dominant Subdominant. % Embedded

The stream characteristic present at each observation is categorized into nine different habitat types (Table 3).

Table 3. Stream character descriptions in use for habitat utilization criteria development on the Trinity River, Trinity Co., California, 1986.

Code	Stream Character
1	Pool
2	Run
3	Riffle
4	Side Channel
5	Off Channel ponding (Beaver Ponds)
6	Backwater
7	Waters Edge
8	Pocket
9	Bar

Surface turbulance is noted as either present or absent for each observation taken. An estimate of percent canopy is made for each observation taken by visually estimating the percentage of the sky which is blocked by the riparian canopy.

Additional data which is recorded for each sampling day includes an estimate of water visibility in feet, stream discharge, study site, water temperature, weather conditions, observers present, and the data and time of sampling.

Data Summary

Habitat use data are being summarized by depth, velocity, substrate, and cover. All habitat use curves have been developed from data collected by direct observation, primarily with a mask and snorkel. Habitat use curves are developed from the frequency of the number of observations at each parameter per species lifestage. The habitat use curves for depth and velocity are hand drawn by fitting a smooth curve through a normalized frequency distribution for each species and lifestage. Normalized bar histograms are used to show habitat use for substrate and cover. All of the substrate curves are drawn from the dominant substrate value observed at this time. When the study is complete, cover and substrate curves will be constructed in their entirety.

Preliminary Results

After two years of data collection 18,555 fish have been seen in 2,418 observations (Table 4).

Table 4. Summary of habitat criteria data collected by direct observation in the Trinity River from January 1985 to June of 1986, Trinity Co., CA.

SPECIES	LIFESTAGE	NUMBER OF OBSERVATIONS	NUMBER OF FISH
Chinook	Fry	594	7583
	Juvenile	356	6364
	Adult	12	92
	Spawning	278	342
Coho	Fry	152	1314
	Juvenile	118	925
	Adult	13	37
	Spawning	102	198
Steelhead	Fry	33	117
	Juvenile	420	933
	Adult	117	208
	Spawning	20	10
Brown	Fry	55	146
	Juvenile	104	235
	Adult	41	48
	Spawning	3	3
	TOTALS	2,418	18,555

Preliminary habitat use curves or histograms for all lifestages of chinook and coho salmon are illustrated in Figures 3 - 8. Curves for all lifestages, except spawning, of steelhead/rainbow trout and brown trout are illustrated in Figures 9 - 14. Use frequency histograms for cover and substrate are based only on the dominant category observed.

Discussion

After a second year of data collection the quality of nearly every species habitat use curve has improved. It appears that more observations are needed for spawning chinook salmon to improve the quality of the velocity use curves. However, the depth use curves are in very good condition. The habitat use curves for all lifestages of coho salmon should be excellent after the final year of data collection is complete. At the present time their quality may be considered good. Development of adult holding curves for both chinook and coho salmon has been of low priority until this year. There should be no problem in obtaining enough observations to complete holding curves for adult salmon by next year. The only problem encountered with obtaining observations on adult holding salmon thus far has been getting accurate depths and velocities, because of the deep water they seem to prefer.

To date, only 33 observations have been made on fry steelhead trout by mask and snorkel , while 420 observations have been made on juvenile steelhead trout. It is apparent that locating fry steelhead trout by direct observation is difficult. Steelhead trout fry may be using habitat areas of very shallow water, where snorkel and mask observations are difficult or they may blend into the substrate so well that they are easily overlooked by the observer. There is also the possibility that tributary streams, where the majority of steelhead trout spawning occurs, are used by fry steelhead trout until they have grown to juvenile size before entering the Trinity River.

The limited number of observations made on adult steelhead trout during 1986 are most likely due to high flows during February, along with zero visibility for over two months last winter. Greater effort will be placed on getting adult steelhead trout observations this coming year. If good weather conditions and clear water exists long enough we feel that enough data points can be collected to yield good habitat use curves by the end of the study.

More observations are needed for all lifestages of brown trout in order to have enough data points for construction of quality habitat use curves. There were very few brown trout fry observed this year compared to last year. The flood flows during February may have washed many fry downstream, distributing them throughout the system. Last year large numbers of fry brown trout were only observed in the upper river.

Validation of Random Habitat Assessments

Available habitat is estimated by taking a minimum of 150 random microhabitat measurements at each study site for each discharge sampled. The sampling locations are determined with previously prepared tables of paired random values. The first value in the pair represented the distance downstream to the next sampling location, while the second value represented the percent distance across the river channel yielding the exact location where the sample is made. Data collected during available habitat sampling is essentially the same as the data collected during fish observation sampling.

Collection of random habitat availability data proved to be a slow and laborious process. We found that at least one full day of sampling is required to successfully obtain 150 observations. As an alternative method to obtaining habitat availability data, habitat information was taken from the IFIM IFG-4 Hydraulic simulation model output to estimate habitat availability at each study site. The method that is used to select vertical habitat measurements from the IFG-4 model is as follows:

1. The total length of the study site and the distances between each transect is determined.

2. The length of habitat which each transect represented upstream and downstream is determined by multiplying the distance to the upstream transect by the weighting factor upstream and by multiplying the distance to the downstream transect by the weighting factor downstream given by the model. The resulting distance up and down are then added together to obtain the total distance of habitat which is representative of the transect.

3. The amount of habitat which each transect represents within the total study site is determined by dividing the transect length by the total study site length.

4. The value determined in the previous step is than multiplied by the number of verticals within the wetted area located along the transect and an additional multiplier to determine the number of verticals to be selected from that transect for the habitat availability assessment. The additional multiplier can be any number selected to yeild a total sample size at the desired level (in this case between 100 and 150).

5. The actual verticals (cells) be be used from each transect are than randomly selected. The method described above is illustrated in Table 5.

All of the verticals selected from each transect in this process are then pooled together to produce an available habitat curves for the study site.

Table 5. Method of selecting random available habitat measurements from an IFG-4 model output to obtain an estimate of habitat availability, Trinity River Flow Evaluation, Trinity Co., CA

LEWISTON DAM SITE

Simulated Flow = 300cfs Study Site Length = 2762 ft

Xsec No.	Wt. Factor Up	Wt. Factor Dn	Cell Distance Up	Cell Distance Dn	Cell Distance Total	Total 2762'	No. Verts.	No. Verts. X5 selected
1	0.0	0.5	0.0	14.0	14.0	.0051	25	0.64
2	0.5	0.5	14.0	19.5	33.5	.0121	25	1.52
3	0.5	0.3	19.5	45.0	64.5	.0234	28	3.27
4	0.7	0.5	105.0	53.0	158.0	.0572	26	7.44
5	0.5	0.5	53.0	40.5	93.5	.0339	23	3.89
6	0.5	0.8	40.5	31.2	71.7	.0260	26	3.37
7	0.2	0.5	7.8	25.0	32.8	.0119	17	1.01
8	0.5	0.5	25.0	75.0	100.0	.0362	22	3.98
9	0.5	0.5	75.0	105.0	180.0	.0652	22	7.17
10	0.5	0.9	105.0	207.0	312.0	.1130	24	13.56
11	0.1	0.2	23.0	32.6	55.6	.0201	27	2.72
12	0.8	0.9	130.4	216.0	346.4	.1254	22	13.80
13	0.1	0.2	24.0	62.2	86.2	.0312	27	4.21
14	0.8	0.5	248.8	79.0	327.8	.1350	32	18.99
15	0.5	0.5	79.0	155.0	234.0	.0847	28	11.86
16	0.5	0.5	155.0	115.0	270.0	.0978	21	10.26
17	0.5	0.5	115.0	25.0	140.0	.0507	35	8.87
18	0.5	0.5	25.0	108.5	213.5	.0773	37	14.30
19	0.5	0.0	108.5	0.0	108.5	.0393	32	6.29

Total number of verticals selected = 137

Data Analysis

Habitat availability curves have been constructed for total depth and mean column water velocity at each study site from data obtained by both random sampling and selection of verticals from the IFG-4 model output. The curves have been fit from frequency distributions of depth and velocity. Two running averages are then made on the frequency distributions to reduce deviations between adjacent intervals that are apparent on some curves. The resulting averaged distributions are normalized to a value of one.

Results

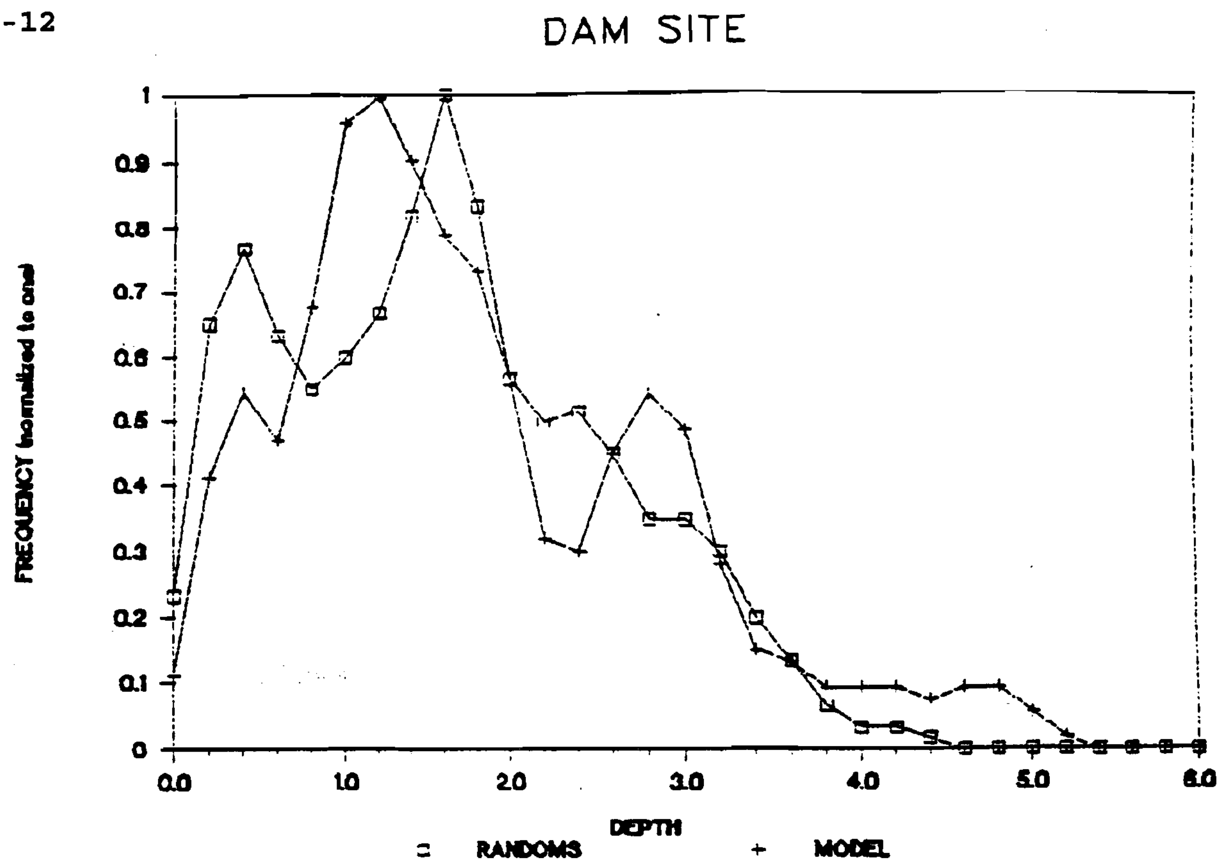
After two years of data collection 1,319 random habitat availability measurements have been taken.

Estimates of habitat availability have been calculated for the upper six study sites, from Lewiston Dam downstream to Steiner Flat. At each of the sites available habitat curves have been constructed for total depth and mean column water velocity from both the random sampling method and the selection of verticals from the IFG-4 model. The curves are drawn together on the same graphs for easy comparisions (Figures 15 - 20).

Discussion

When comparing the two habitat availability estimates, one generated by random sampling and one generated from selection of verticals off of the IFG-4 model, the available habitat curves for velocity are similiar for each study site except for the Lewiston Dam and Bucktail sites.

At the Lewiston Dam site there is an inverse relationship displayed for velocities between 0.8 ft/sec and 2.2 ft/sec. The velocity curves generated from the model show an available habitat value of 0.9 at a velocity of 1.0 ft/sec and a value of 0.3 habitat available at 1.8 ft/sec, while the random sampling shows a lower value 0.3 at 1.0 ft/sec and a greater value 0.8 for 1.8 ft/sec. A possible explanation for the models deviation from the random lies in the weighting factor values which are assigned each transect within the IFG-4 methodology. The lowest possible weighting factor that can be assigned a transect is 0.1. When assigning a weighting factor to a riffle transect, for example, a factor of 0.1 may be overestimating the habitat represented by the riffle. In these cases a weight factor below 0.1 would be more representative. Should this be the case, too many random verticals would be selected from these riffle transects, thus creating more available habitat at velocities associated with riffles, approximately 1.0 ft/sec. In turn, this overestimation of velocities associated with riffles would cause an underestimation of higher velocities (2.0 ft/sec) found in the more abundant shallow runs, which are present at the dam site.



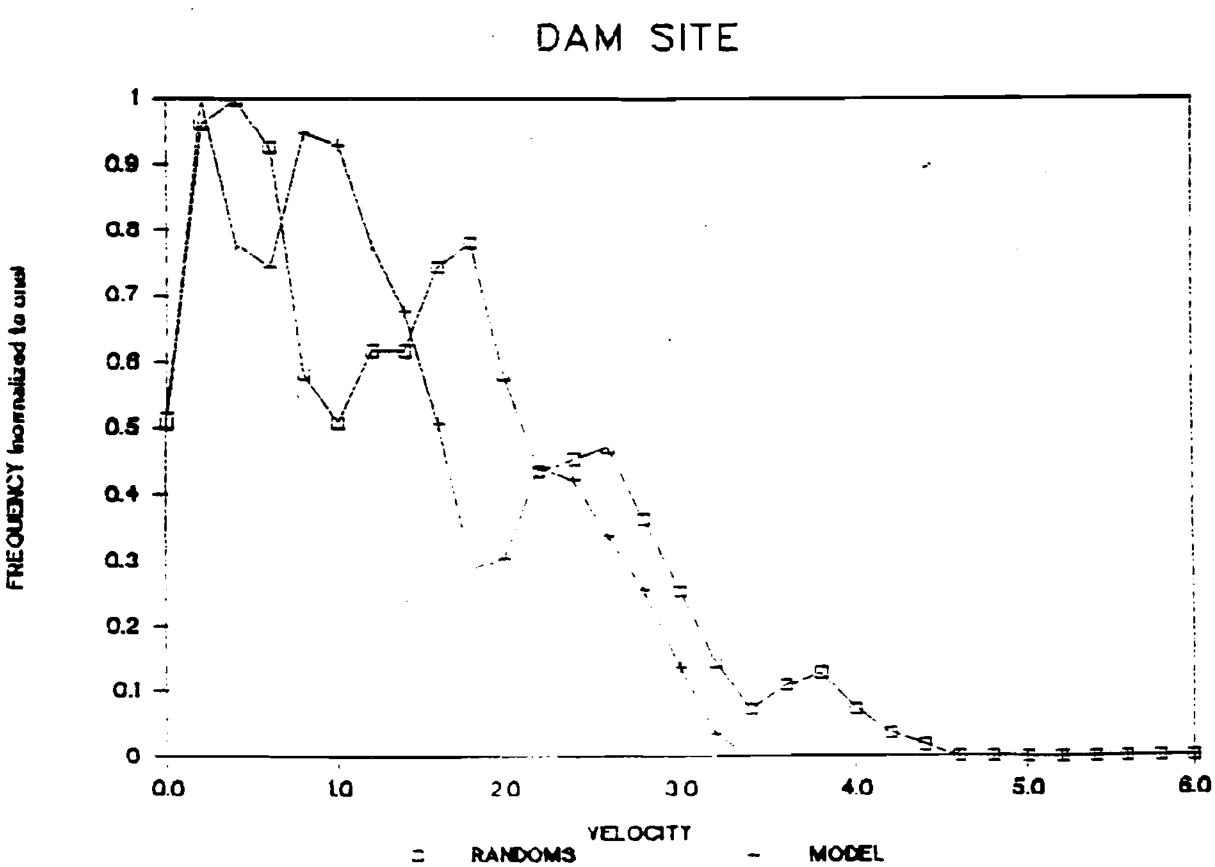
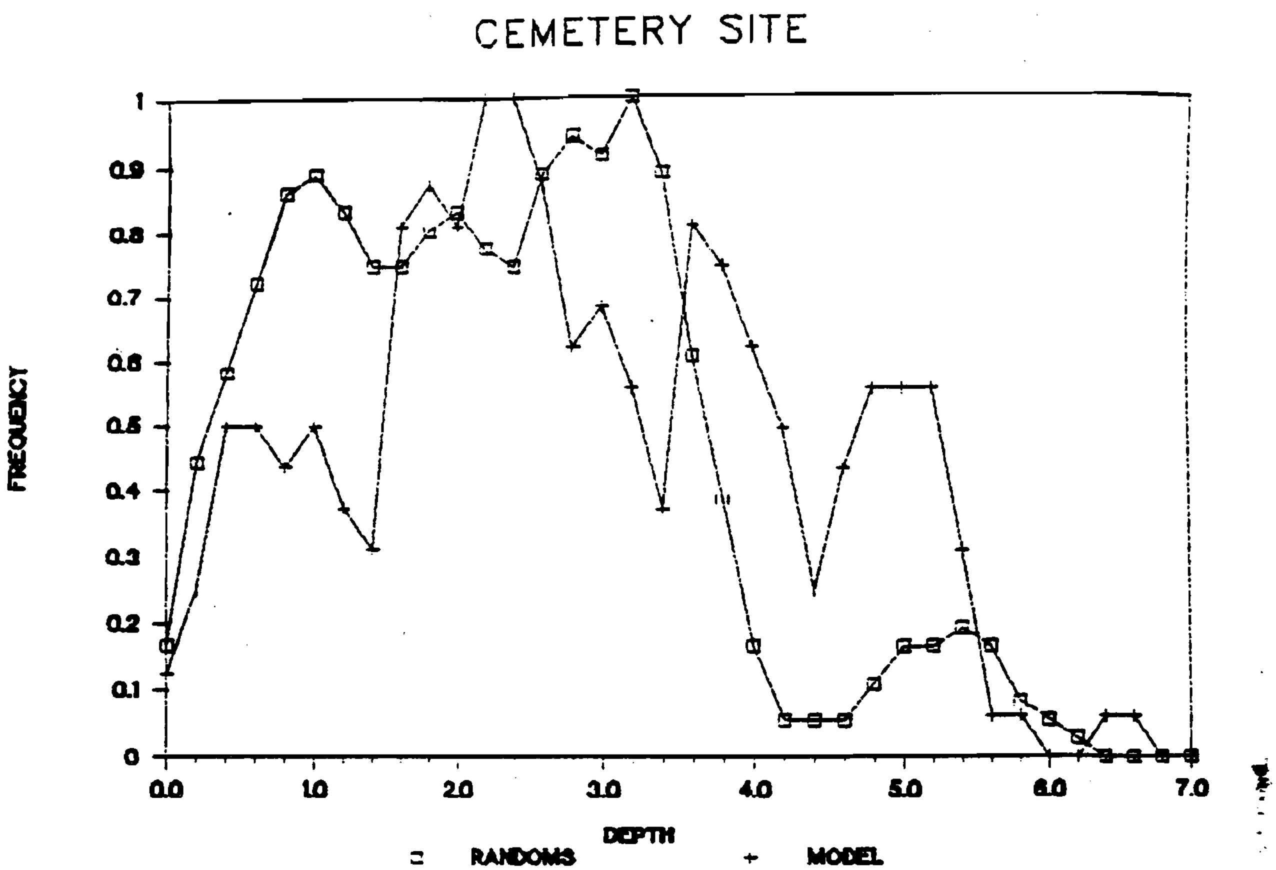


Figure 15. Available Habitat for the Lewiston Dam study site, Trinity River Flow Evaluation Study, 1986.



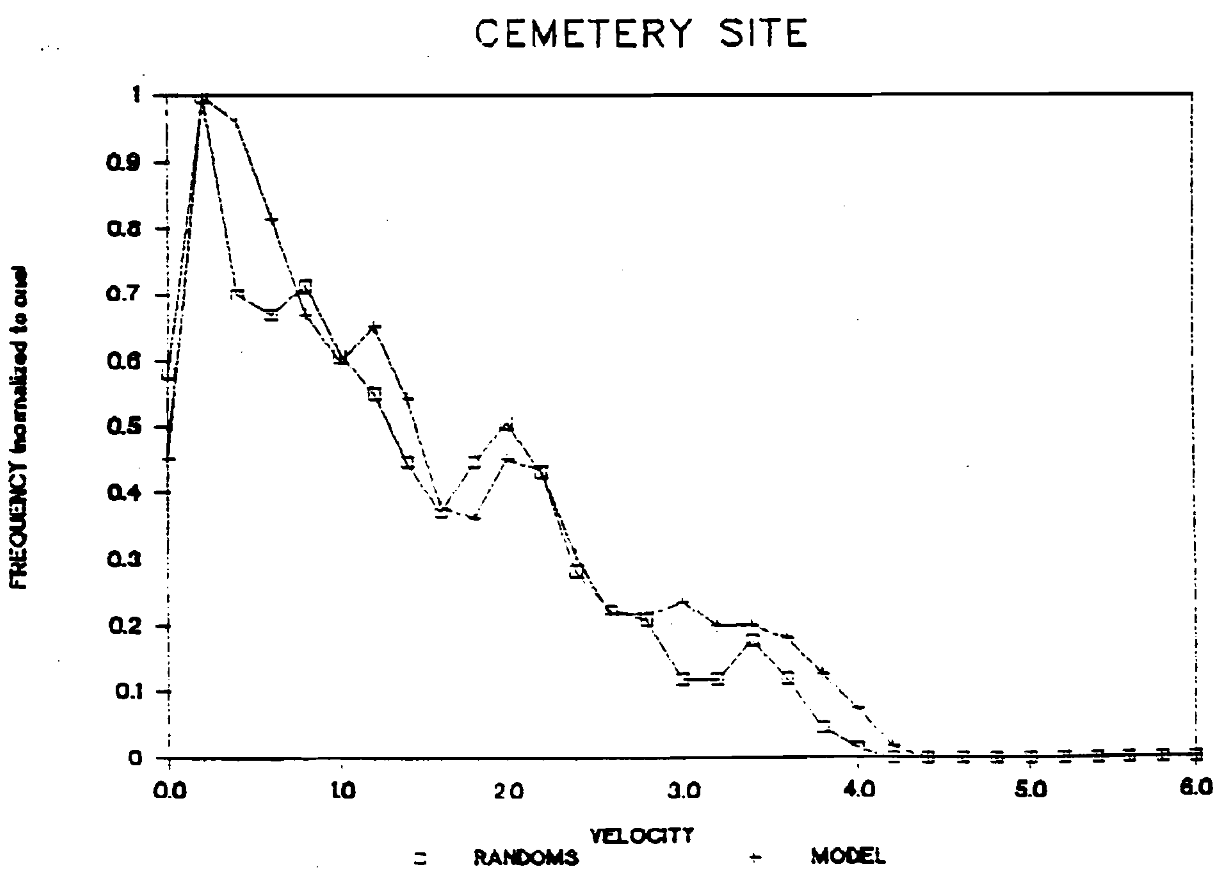


Figure 16. Available Habitat for the Cemetery study site, Trinity River Flow Evaluation Study, 1986.

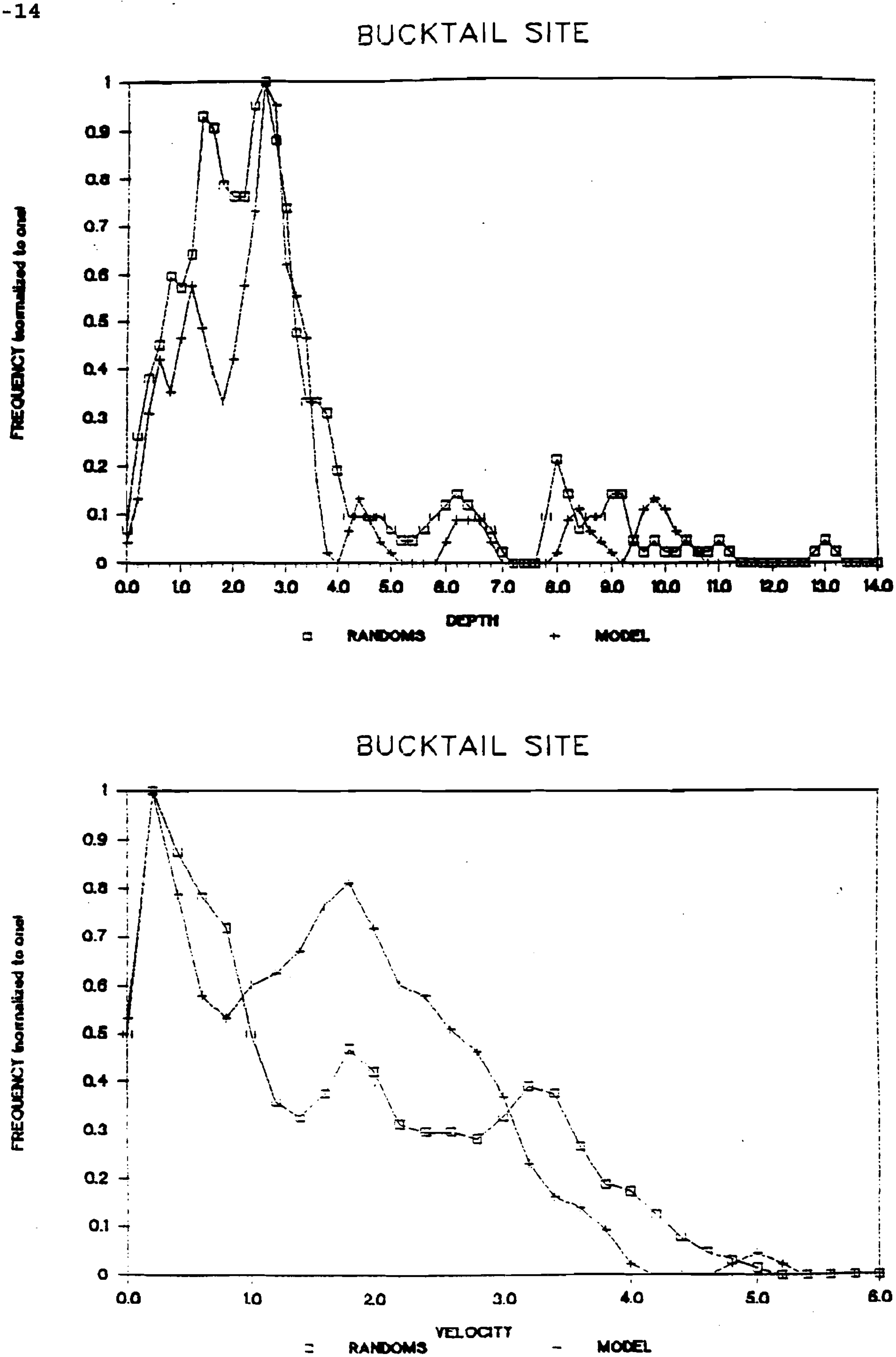
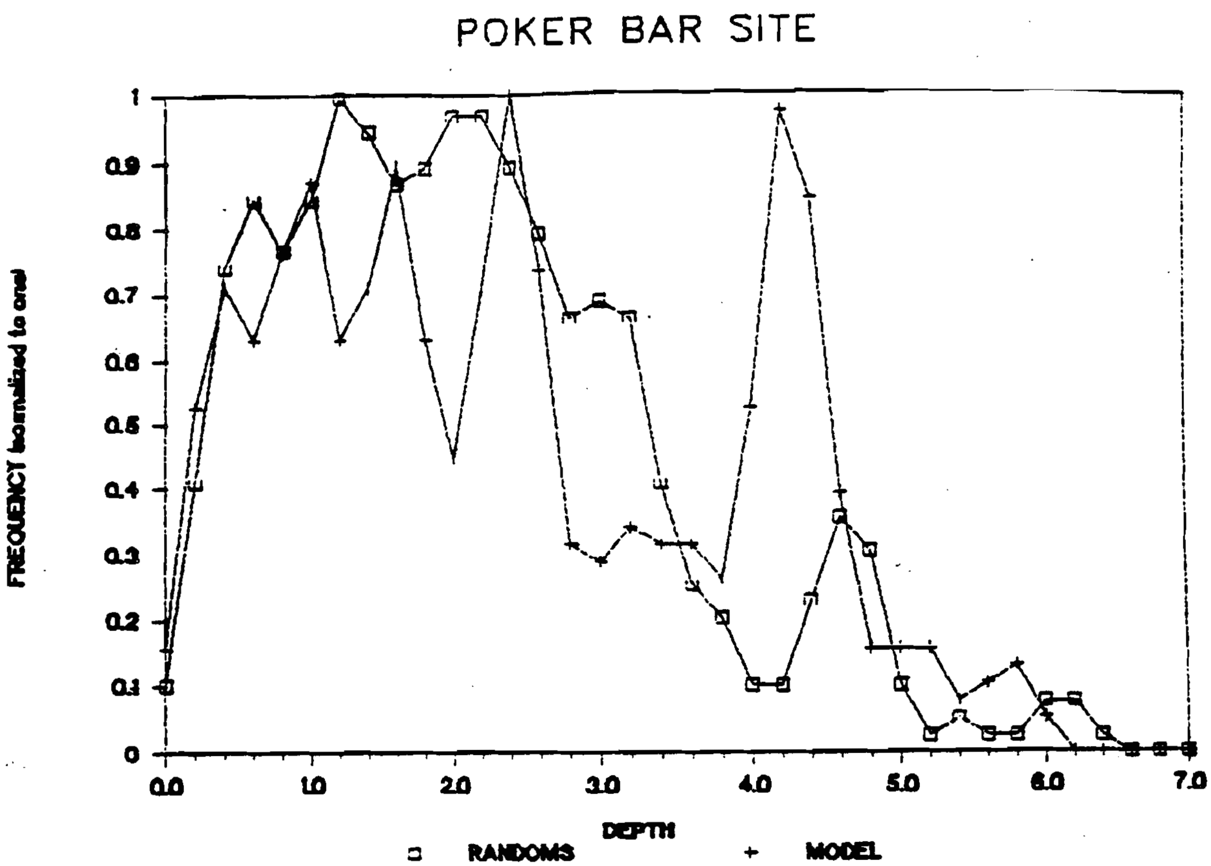


Figure 17. Available Habitat for the Bucktail study site, Trinity River Flow Evaluation Study. 1986.



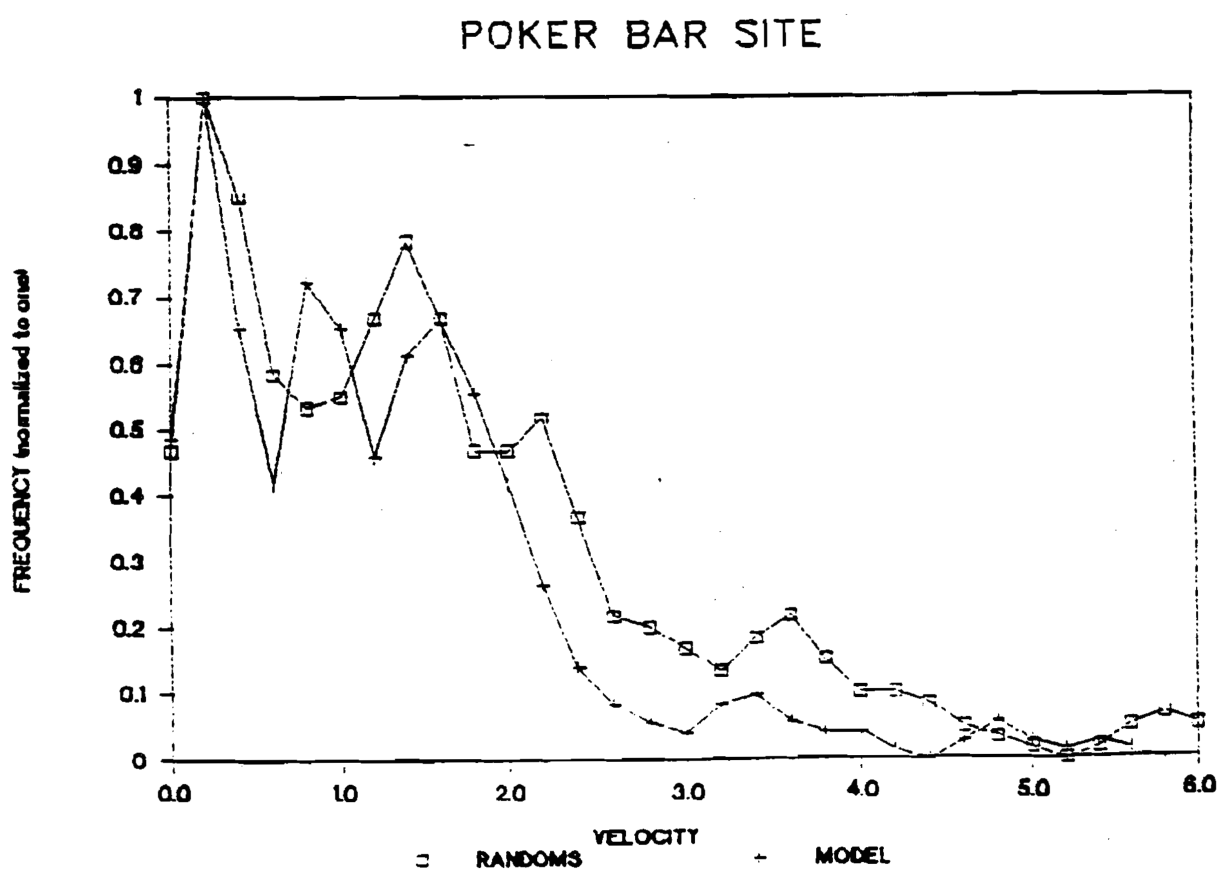
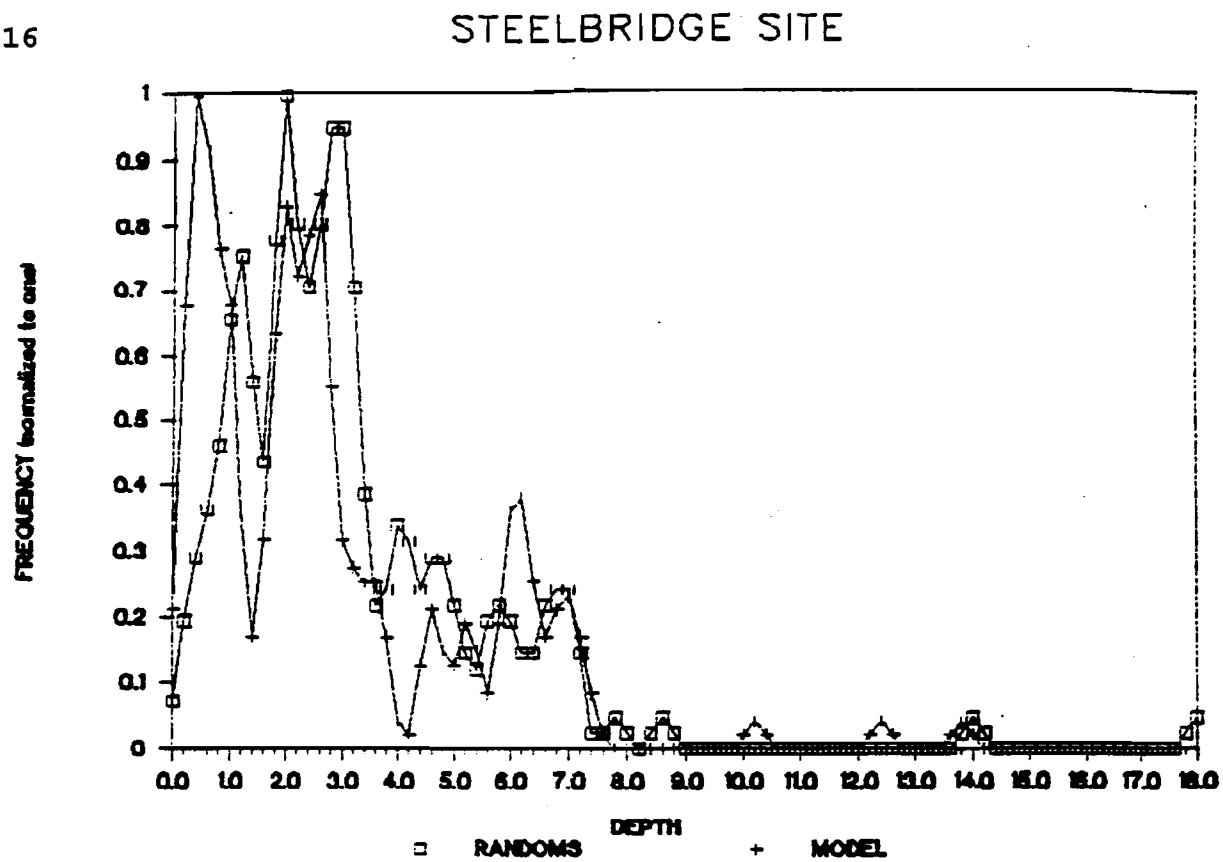


Figure 18. Available Habitat for the Poker Bar study site, Trinity River Flow Evaluation Study, 1986.



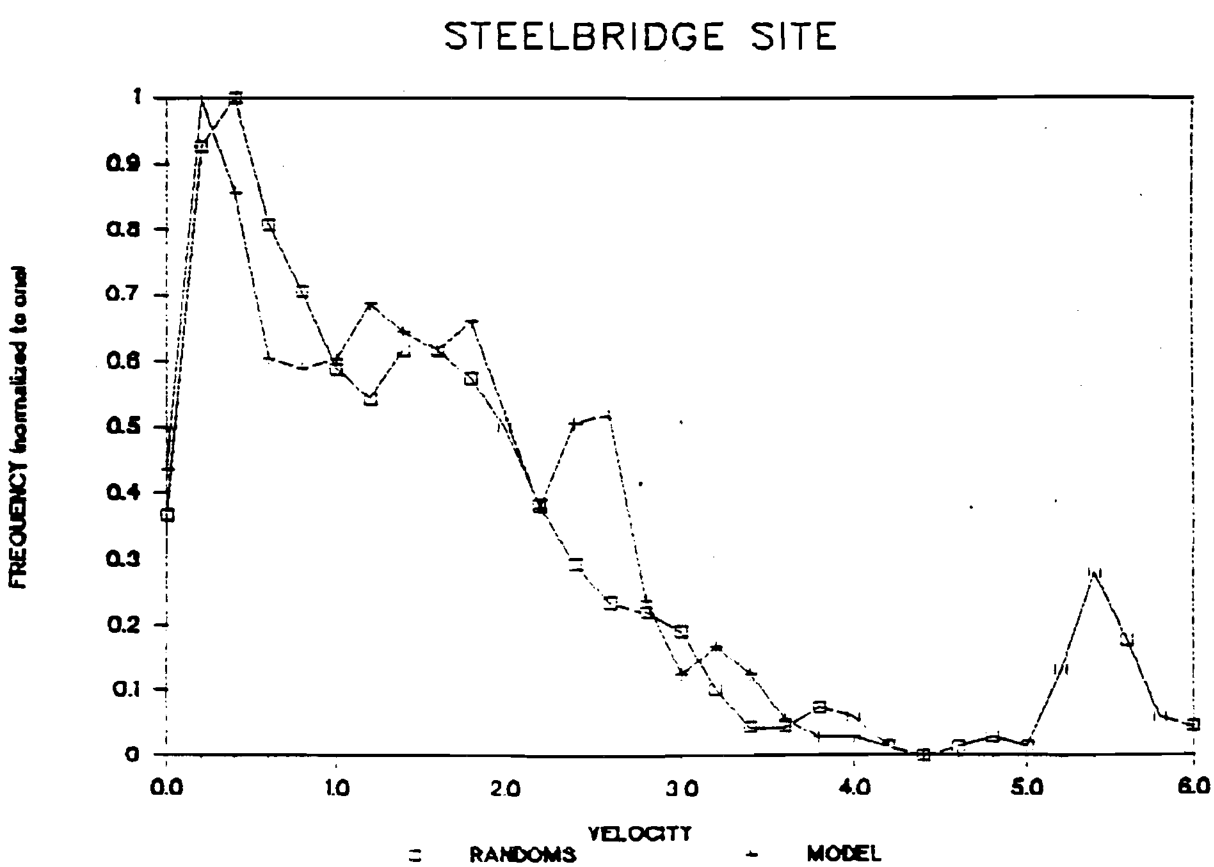
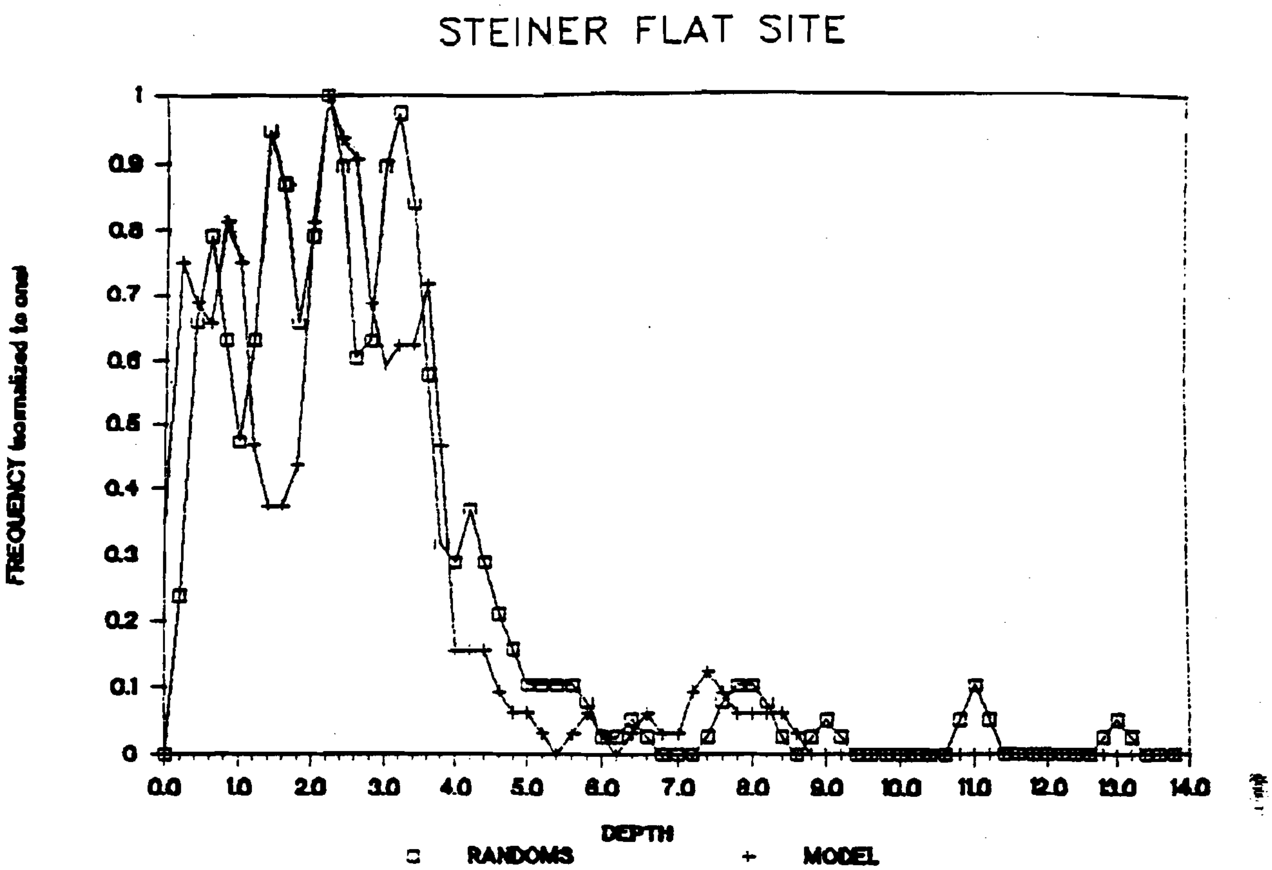


Figure 19. Available Habitat for the Steelbridge study site, Trinity River Flow Evaluation Study, 1986.



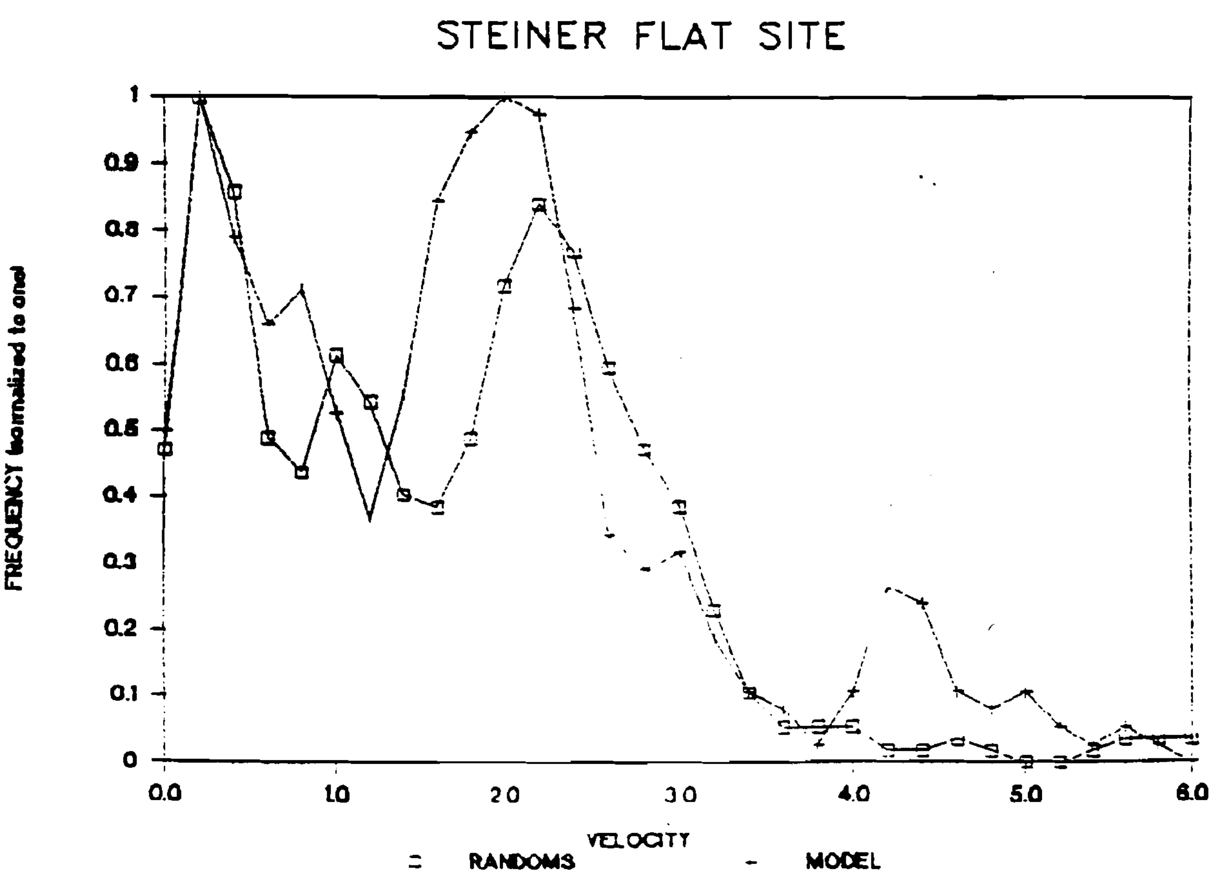


Figure 20. Available Habitat for the Steiner Flat study site. Trinity River Flow Evaluation Study. 1986.

The two velocity curves for available habitat at the Bucktail site differ between 1.0 ft/sec and 3.0 ft/sec. In this velocity range the model shows a greater value of available habitat than was observed. In this case three IFIM transects were located in a pool below a chute in the middle of the study site. While random sampling at the Bucktail site, this section of habitat was not sampled because of the inability of the snorkeler or the raft and equipment to get observations because of deep and relatively fast water velocity. The IFIM model is able to sample these areas because of proper equipment (boat, sounding gear, and cable). This may be an explanation of why the model generated available habitat is greater than the random generated available habitat at these velocities. The model generated available habitat for velocity is therefore probably a better estimate for the Bucktail site.

The habitat availability curves for depth generated from the two sampling methods display similiar habitat available estimate values at all but two sites. The available habitat curves for depth at the Cemetery site differ greatly. This may be explained by the fact that the area sampled by the random observation method is greater in length than the river length within the upper and lower transects of the IFIM study site. What is difficult to expain, however, is why the velocity curves for the Cemetery site so closely resemble one another.

The model generated available habitat curve for depth at Poker Bar shows a much greater amount of habitat at depths between 4.0 and 4.6 feet. Random habitat sampling was not conducted on the right channel of a long island located in the center of the study site, because preference data collection has not been collected in this area. However, the model did simulate this channel. If not for this discrepancy, the two available habitat curves from each method would probably be very similiar.

It appears that the major difference between available habitat curves generated from the two sampling methods are mainly caused by the inability of a snorkeler and raft to sample both deep water or swift water effectively, whereas, the Instream Flow Methodology with better equipment and greater manpower can effectively sample such habitat types. Another problem evident here is that the preference study site boundaries were defined before the selection of IFIM transects, therefore the preference study sites are sometimes larger than the area defined by the upper and lower boundaries of the IFIM transects. Elimination of this study site boundary discrepancy in future studies will certainly justify the use of habitat availability curves generated by the IFIM model for preference curve development. The only problem found with using habitat availability curves generated from the IFIM model may be the overestimation of some habitat types because of inaccurate weighting factors. This problem may be resolved by inserting more transition type transects into the study site.

APPENDIX D

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION STUDY

1987

U.S. Fish and Wildlife Service
Division of Ecological Services
Sacramento Field Office
2800 Cottage Way, Rm. E-1803
Sacramento, California 95825

Prepared by
the staff of

The Trinity River Flow Evaluation Study
P.O. Box 174
Lewiston, California 96052

of available habitat estimates obtained from IFG-4 program output were found to yield similar results (Aceituno and Hampton, in press; U.S. Fish & Wildlife Service, 1986). Use of habitat availability estimates generated from IFG-4 program output allowed greater effort to be focused on habitat use data collection in the last year of data collection. Effort also shifted to the upper Trinity River, above the North Fork Trinity River confluence, because accurate discharge estimates were not obtained during lower river sampling in the previous year. Without these discharge estimates modeling of lower river habitat availability was impossible. Fortunately this did not affect any significant sampling effort for 1985 since lower river habitats were rarely sampled because of unfavorable conditions such as high water and low water visibility.

Chinook salmon fry were found in marginal habitat types where slow water velocities and abundant cover items were present. Woody debris, undercut banks, and cobble substrates provided fry salmon with velocity shelters and escape cover from surface-feeding predators. As chinook salmon grew larger they became less dependent on marginal habitats and began to use areas with higher water velocities in deeper water. Object cover still played a key role in providing velocity shelters in deep run and riffle habitats. In deep pool habitats, schools of juvenile chinook salmon positioned themselves in relationship to ever changing eddies and shear velocity zones where food items could be easily taken in the drift. In pool habitats the majority of juvenile salmon would feed near the water surface and would flee to deep water when frightened from above. At night time fry and juvenile chinook salmon congregated into slow velocity habitats in close proximity to the river substrates or cover items.

Spawning chinook salmon preferred depths ranging from 1.1 to 1.2 feet with mean column velocities from 1.3 to 2.0 feet per second. Because the majority of spawning was done at depths near 1.0 feet, category II criteria describing nose velocities and mean column velocities selected by spawning chinook salmon were similar. Preferred spawning substrates ranged from 2 to 6 inch diameter gravel and cobble that were less than 40% embedded in fines. The majority of redds were located in close proximity to the river banks where either overhanging vegetation, emergent aquatic vegetation, or woody debris was located. Cover did not seem to be nearly as important as water velocity in determining redd site suitability by chinook salmon. Adult salmon did appear to be frightened more easily when located in open areas versus areas located in shade or near large cover items.

Fry coho salmon selected similar microhabitats as fry chinook salmon, and the two species were often found together in the same schools. Aggressive behavior between the species was rarely observed. As coho salmon became larger they did not shift their habitat selection to areas of faster velocity as did chinook salmon. Juvenile coho salmon sought out slow water habitats present in backwaters, side channels, and marginal habitats adjacent to long slow runs and pools. These microhabitats nearly always contained abundant cover in the form woody debris, aquatic vegetation, and overhanging vegetation. Substrates present in these habitats was composed of fine sand, silt, organic debris, or larger particles that were highly embedded in fines. Habitat selection differences provided for species segregation between juvenile coho and chinook salmon.

Spawning coho salmon preferred depths from 0.9 to 1.2 feet with mean column velocities ranging from 0.8 to 1.2 feet per second. For redd construction coho salmon selected smaller substrates than chinook salmon. Coho salmon spawned in substrates composed of gravels ranging in diameter from 1 to 3 inches that were embedded less than 20% in fines. On the Trinity River nearly all of the coho salmon spawning is done in the upper river within 3 miles of Lewiston Dam. This reach contains a large number artificially constructed spawning riffles and may not be very representative of natural habitat conditions that exist in the majority of the Trinity River. This is particularly true of the substrate conditions present in the upper river where large amounts of decomposed granitic sand are absent.

Development of category III criteria describing habitat preference for fry steelhead trout could not be developed because of an insufficient number of use observations taken during the study period. This was the result of low adult escapement levels during 1985 and 1986. The total number of adult steelhead taken at Trinity Hatchery in 1985 and 1986 was 142 and 461 respectively. From the use observations that were made, fry steelhead appeared to prefer marginal habitats adjacent to riffles, and runs. Fry steelhead selected focal points in close proximity with the substrate or near cover items which provided a velocity shelter. Unlike fry chinook or coho salmon, fry steelhead were often found in turbulent water present in shallow riffles. Their association with velocity shelters on or near the stream bottoms allowed them to use these more turbulent microhabitats. Fry steelhead were rarely observed in monotypic habitats present in long slow runs or pools.

Juvenile steelhead trout preferred run, riffle, and riffle-pool transition habitats that provided a high degree of velocity diversity. Preferred depths ranged from 2.0 to 3.5 feet with mean column velocities from 1.1 to 1.4 feet per second. Juvenile steelhead actively defended feeding stations in riffles and across the tail end of run habitats. Object cover, boulders, large cobbles or woody debris, played an important role by providing velocity shelters where juvenile steelhead could establish feeding stations with little effort. When found in riffle-pool transition habitats groups of juvenile steelhead were often seen feeding in the same locations without displaying any aggressive behavior among themselves. In these microhabitats steelhead were usually positioned underneath areas of high surface water velocity along the ledge located at the upper boundary of the pool. In these locations juvenile steelhead could maintain focal points in near zero velocity water and still take advantage of drift organisms provided by the riffle upstream. Cover objects were seldom present in these riffle-pool transition habitats, however, surface turbulence did provide concealment from surface predators.

Shear velocity zones, areas of rapid velocity change, proved to be an important hydraulic characteristic present in the microhabitats selected by juvenile steelhead trout. Shear velocity zones provide juvenile steelhead with opportunistic feeding stations, where focal points can be established in slow water velocity and still be in close proximity to high water velocity areas where food, available in the form of drift, is more easily accessible and more abundant. Net energy gain in these microhabitats is probably optimized because less energy is expended to maintain focal points and distances traveled to capture prey items are reduced. This behavior characteristic caused problems when developing preference criteria that accurately describe preferred water velocities for juvenile steelhead. During field data collection, if water velocities are recorded at the focal point, the resulting criteria does not consider water velocities across the shear velocity zone, yet it is this hydraulic characteristic which the target species is most likely selecting for. The development of conditional criteria that consider both focal point velocity and water velocities in adjacent cells may alleviate these problems.

Collection of habitat use data for adult steelhead trout was hindered by poor sampling conditions and low escapement numbers to the upper Trinity River. Adult steelhead trout spawn from December through April when winter storms commonly cause increased turbidity and flows which prevent effective use sampling. Returns of adult steelhead to Trinity Hatchery from 1985 to 1987 were 142, 461, and 3,780 respectively. The presence of a fairly good run in 1987, combined with good sampling conditions, gave the opportunity to obtain an adequate number of spawning observations to develop category III criteria. Steelhead trout preferred depths of 1.1 feet with mean column velocities from 1.1 to 2.1 feet per second. Preferred substrates were composed of gravels from 1 to 3 inches in diameter that less than 20% embedded in fines.

The concept that category III criteria, by eliminating habitat bias, may be transferred to other streams or rivers is questionable. Development of category III criteria is dependent on the available habitat present within the area of study. Therefore, if a habitat type is not present within the study area the influence of that habitat type on the target species habitat selection will not be represented in the resulting category III criteria. Based on this fact, it is important that other researchers validate that the available habitat in the system where the category III criteria are being considered for use is similar to the available habitat present in the system where the category III criteria were developed. Only after the available habitats of the two systems have been found to be similar should category III criteria be transferred.

APPENDIX E

TRINITY RIVER FLOW EVALUATION

1988

U.S. Fish and Wildlife Service
Division of Ecological Services
Sacramento Field Office
2800 Cottage Way, Rm. E-1803
Sacramento, California 95825

Prepared by
the Staff of

The Trinity River Flow Evaluation
P.O. Box 174
Lewiston, California 96052

December 1988

3. WINTER HABITAT USE

Introduction

Steelhead trout (Salmo gairdneri) and coho salmon (Oncorhynchus kisutch) juveniles rear in freshwater for one or more years before migrating to the ocean. During the spring and summer growing seasons Trinity River steelhead trout juveniles occupy run, riffle, and riffle-pool transition type habitats, while coho salmon juveniles are typically found along stream margins, in side-channels, or backwater pools, where slow water and abundant cover are present (U.S. Fish & Wildlife Service, 1987). During the fall and winter months, when water temperatures begin to drop below 48 - 50 degrees Fahrenheit, juvenile salmon and trout in the Trinity River shift their habitat selection to sheltered areas containing abundant cover. Seasonal changes in habitat selection by juvenile salmonids is well documented in the literature (Bjornn, 1971; Bustard and Narver,1975a,b; Cunjak and Power, 1986; Everest and Chapman, 1972; Hartman, 1965; Heifetz et al., 1986; Peterson, 1982a,b; Swales et al., 1986; Tschaplinski and Hartman, 1983). In Idaho streams Bjornn (1971) found that fall seasonal movements of nonsmolt trout and salmon correlated best with the amount of cover provided by large rubble substrate. In Ontario, Canada, Cunjak and Power (1986) found that during the winter both brook and brown trout exhibited a strong preference for positions beneath cover in slow water. Swales et al. (1985) found side channels and off channel ponds to be the preferred overwintering habitats of juvenile coho salmon, while steelhead trout juveniles took shelter in rock crevices or beneath large substrate material. Bustard and Narver (1975a) found that pools formed by upturned tree roots and logs were important wintering areas for coho salmon and age 1+ steelhead trout, while rubble was the principal source of cover for age 0 steelhead trout. Heifetz et al. (1986) also found that most wintering coho salmon, dolly varden trout, and steelhead trout occupied deep pools with cover (i.e., upturned tree roots, accumulations of logs, and cobble substrate). Immigration of juvenile salmon and trout from main stream habitats into side channels, sloughs, off channel ponds, and tributary streams in search of suitable winter habitat has been shown to occur by Tschaplinski and Hartman (1983) and Peterson (1982b).

The goal of this study was to obtain a better understanding of the habitat requirements of overwintering juvenile salmonids in the Trinity River. This information is important to the continued efforts of the Flow Evaluation and to the Trinity River Management Program and their goal to restore the anadromous fishery of the Trinity River to historical levels.

E-2 Study Area

Five study sites were selected, each of which contain different microhabitats that would be available to juvenile salmonids during the winter season. Two sites are located in side-channels, while the remaining three sites are contained within the main river channel.

The Moose Lodge side-channel is located behind the Moose Lodge in Lewiston along the northwest bank of the river. The channel is approximately 1200 feet long and may be broken down into an upper and lower section, with each representing a different habitat type.

The upper section is approximately 400 feet in length and is composed of two channels with the majority of the flow passing through the right channel looking downstream. This channel may be described as a long, slow run. Water velocities are slow, less than 1.0 cubic feet per second, and total depths throughout the majority of the channel rarely exceed 2.0 feet. The substrate is composed of cobbles highly embedded in clay and silt. There are a few pockets of clean gravel and cobble available but they are limited in volume. The riparian community consists of grasses, willows, and alders. Instream cover is limited to occasional down logs, cobble pockets, emergent and submergent aquatic plants, and overhanging vegetation.

The lower channel is approximately 700 feet in length with a discharge of 17 cubic feet per second when the river discharge equals 300 cfs. A small pool is present at the beginning of this section where the two channels from the upper section merge. The remainder of the channel is composed of three run-riffle sequences, with the lower riffle joining the main river. This entire section contains cobble and large gravel substrates. Several boulders are also present throughout this reach which provide some instream cover. Cover is also provided by large mats of submergent aquatic vegetation which are scattered along the channel. Riparion vegetation is abundant along the left bank, however, along the right bank the riparian is generally offset from the edge and is limited in developement to small willows, with the exception of two large alders.

The second side-channel selected is located at river mile 96, and is referred to as Indian Creek side-channel in this report. The channel is located along the left bank of the Trinity River and is approximately 900 feet long. Discharge through the channel was less than 8 cubic feet per second during the study period. The upper 200 feet of the channel is composed of one small pool at the inlet to the channel followed by a short section of shallow riffles and runs. A small area of braided channel is also present in this section. The substrate here is composed of small gravel and sand, however, some cobbles are present in the upper pool.

Below this upper area, the channel forms a slow deep run or pool. The substrate changes to sand and then silt proceeding downstream. The depths range from about 1.0 to 4.0 feet. The channel begins to braid considerably in the lower reaches as pool habitat turns to riffle. The substrate in the lower reaches of the channel is similiar to that already described for the upper segment, being composed of small gravel and sand. Both banks of the channel contain mature riparian communities. This rich riparian community provides large volumes of woody debris to the channel, which is the dominant instream cover type available. Other sources of cover are provided by emergent and submergent aquatic plants, cut banks, and overhanging vegetation.

The three main river study sites were located in a run and riffle sequence above sawmill pool near the Cemetery in Lewiston and in a backwater located at the upstream end of Poker Bar. The run and riffle habitats both contain substrates largely composed of cobbles ranging from 3 to 12 inches that are less than 20 % embedded in fines. Bedrock outcroppings are located at various locations in both habitats as well. Boulders provide some instream cover across the entire width of the riffle while overhanging vegetation and instream organic debris provide some cover along the stream edges. Cover items are not as available within the run habitat, but some organic debris is present along the left bank. Water velocities in the run mostly range between 0.5 to 2.0 feet/second, while depths are generally less than 3.0 feet. Water velocities in the riffle are slightly higher and depths shallower. The velocity diversity in the riffle is considerably higher than the velocities present in the run, as would be expected.

The backwater at Poker Bar is located on the right bank at the upstream limit of subdivision development. The backwater is a shallow slack water area approximately 150 feet long by 50 feet wide. The substrate may be described as heavily silted cobble. Cover is provided by a few small willows both instream and along the bank. There are also some large areas of aquatic moss which provide some cover. Water depths are less than 1.0 feet over the majority of the area and water velocities are zero or very slow.

Methods

Fish population estimates were conducted by multiple pass depletion using a backpack electrofisher. In side channel and backwater habitat types the upper and lower boundries of each site were blocked with 3/16 inch mesh seines to prevent fish movement into or out of the area while sampling. In the Moose Lodge side channel three sites each 50 feet in length were selected. One site was located in the upper right channel, while the other two sites were located in the lower channel. The Indian Creek side channel was divided into nine one hundred foot sections. Two of the nine sections were selected by judgement, one to represent the slow run pool habitat and one to represent the riffle habitat. The Poker Bar backwater was simply split in half providing two 75 foot sections, one of which was selected by coin toss.

In the main river riffle and run habitat types, discrete areas were blocked off by anchoring nets and bag seines with a combination of ropes, rebar and fence posts. The upstream entrance to the area was not sealed. It was assumed that fish movement was minimal because of the cold water and therefore movement out of or into the sample site would not occur. Direct observations conducted by us have verified the absence of any fish up in the water column during this time of year. The area was then electrofished, starting at the open upstream end, proceeding downstream toward the bag in the seine. Four sites were randomly selected within the riffle and three sites within the run.

Fish depletion data was analyzed with the use of a maximum weighted likelihood (MWL) microcomputer program written by Conner (1987). References used in the writing of this program, as cited by Conner (1987), include Carle and Strub (1978) and Zippin (1958).

Habitat use data were collected at all study sites with the use of a backpack electroshocker. At each site fish were shocked in an upstream direction, one person operated the electroshocker while a second person netted stunned fish. A numbered float with a weight attached was used to mark capture locations. When exact focal point locations of sampled fish couldn't be determined no data was collected for that observation. Once all of the floats were deployed we discontinued electroshocking and went back to collect microhabitat information for each float marking a capture location.

The data collected included total depth (feet), mean column velocity (feet/second), substrate, and cover. Substrates were described as fines (< 4mm), gravel (4 - 75mm), cobble (75 - 300mm), boulder (300mm +), or bedrock. Substrate values were recorded as dominant, subdominant, and percent embedded in fines. The dominant substrate was defined as the largest abundant partical size present. The cover types recorded include cobble, boulder, brush, logs, undercut bank, overhanging vegetation, and aquatic vegetation.

Habitat utilization criteria were developed through the use of frequency analysis as described by Bovee (1986), Bovee and Cochnauer (1977), and Slauson (1988). Total depth and mean column velocity frequency intervals were determined by Sturges Rule (Cheslak and Garcia, 1988).

In order to increase both the sample size and validity of the habitat use criteria developed, microhabitat data collected during the winters of 1985 and 1986 for habitat preference criteria development (Hampton, 1988) were included here. This data was collected using the same methods within the Instream Flow Incremental Methodology study areas in the upper Trinity River.

Results

Fish population and microhabitat use data were collected from December 15 through February 11. Water temperatures ranged from 42 to 48 degrees Fahrenheit during the sampling period.

Steelhead Trout. Steelhead trout juveniles captured in the Moose Lodge side-channel ranged in fork length from 54 to 193mm with an average of 93.8 mm. The highest densities of juvenile steelhead were found in the lower section of the Moose Lodge side-channel (1.21 fish per square meter), followed by Cemetery riffle and run habitats which had densities of 0.32 and 0.22 fish per square meter respectively (Figure 1). Steelhead trout densities were highest in those microhabitats which contained cobble and boulder substrates. Indian Creek side-channel, which contains primarily silt substrates and large amounts of woody debris, only yielded 0.07 fish per square meter. In the upper Moose Lodge side-channel, where the substrates are primarily composed of cobbles embedded in clay, only 0.05 fish per square meter were found. No juvenile steelhead were found in the backwater habitat of Poker Bar, which contained large quantities of sand and highly silted cobble substrates.

Habitat use criteria (category II) for overwintering juvenile steelhead are presented in Figure 2. Microhabitats selected by wintering steelhead juveniles contained slow water velocities with clean cobble substrates. Focal points where nearly always located underneath cobbles or boulders.

Brown Trout. Brown trout juveniles captured in the Moose Lodge side-channel ranged in fork length from 63 to 205 mm with an average fork length of 89.5 mm. Habitat densities of juvenile brown trout ranged from 0.10 fish per square meter in the lower Moose Lodge side-channel to 0.01 fish per square meter in the backwater at Poker Bar (Figure 3). Densities of juvenile brown trout were consistently lower than densities of juvenile steelhead at all sites except Poker Bar, where no steelhead were sampled, and at upper Moose Lodge side-channel, where the densities where equal.

Juvenile brown trout, much like juvenile steelhead, were found holding in intersticial areas between cobbles or under boulders (Figure 4). Mean column velocities selected by wintering juvenile brown trout were slightly slower than the velocities selected by juvenile steelhead with a velocity of 0.3 ft/sec being most utilized.

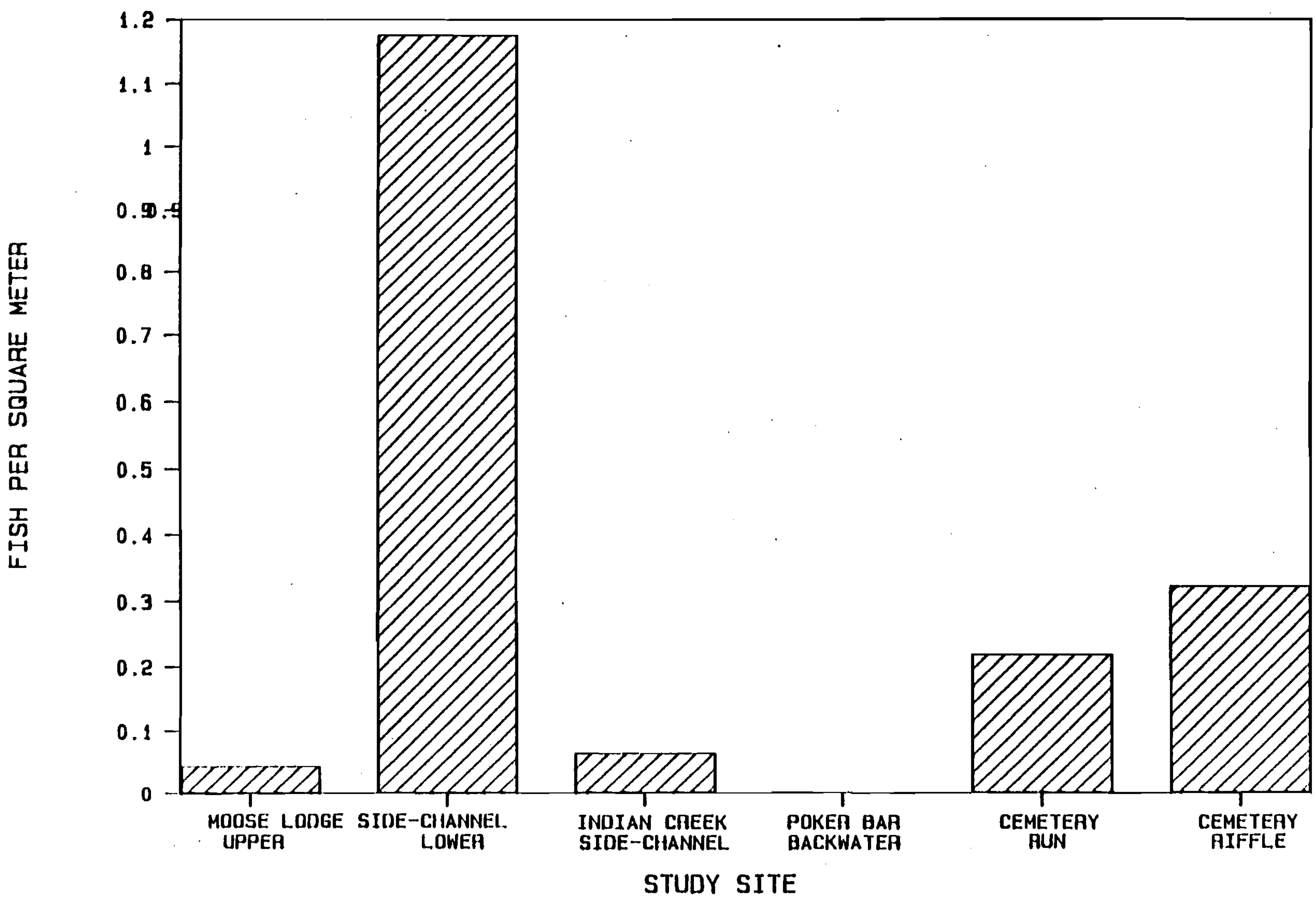


Figure 1. Densities of juvenile steelhead trout collected in five study sites located in the upper Trinity River, California 1988.

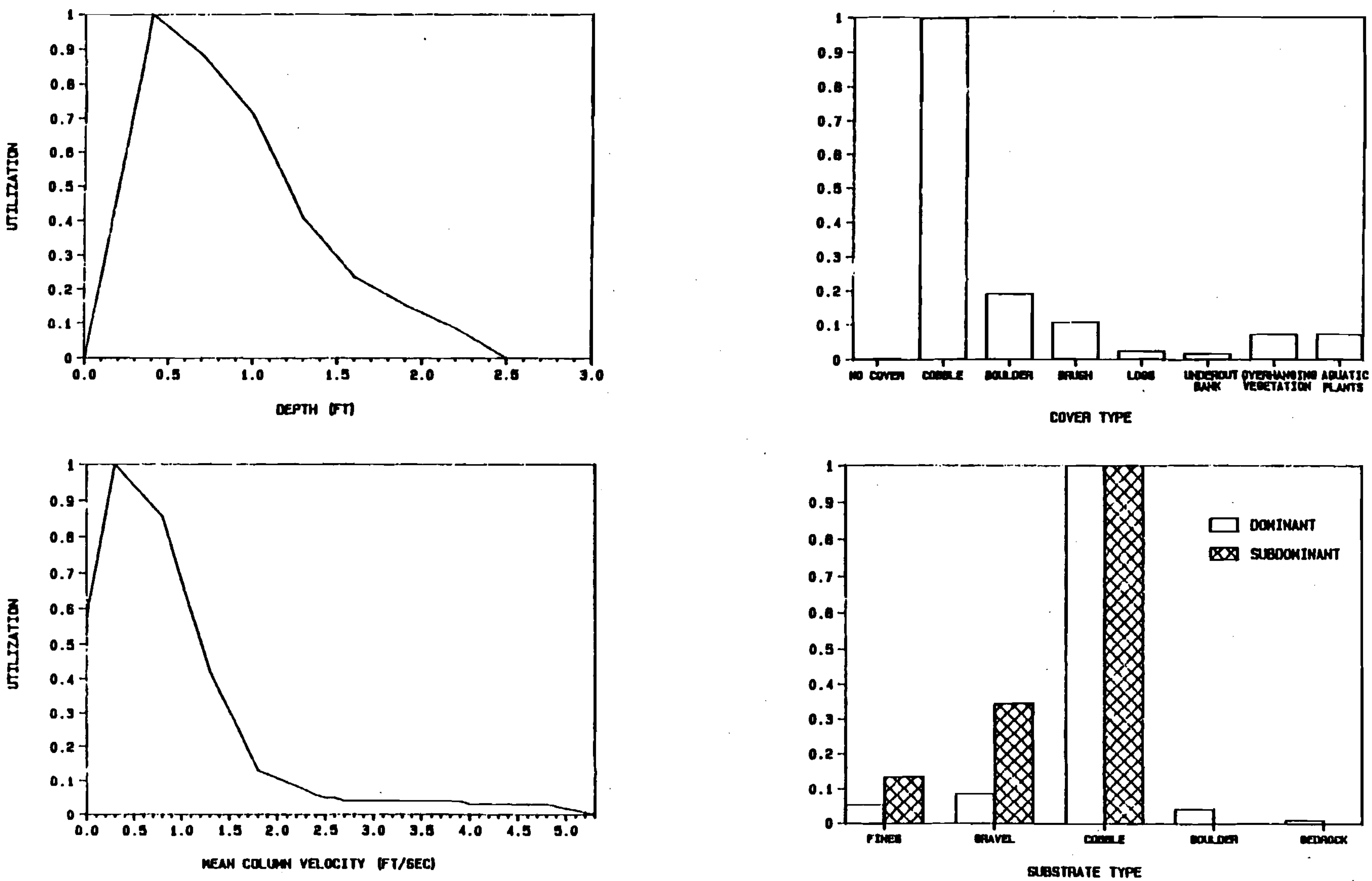


Figure 2. Habitat use by overwintering juvenile steelhead trout in the upper Trinity River, California 1988.

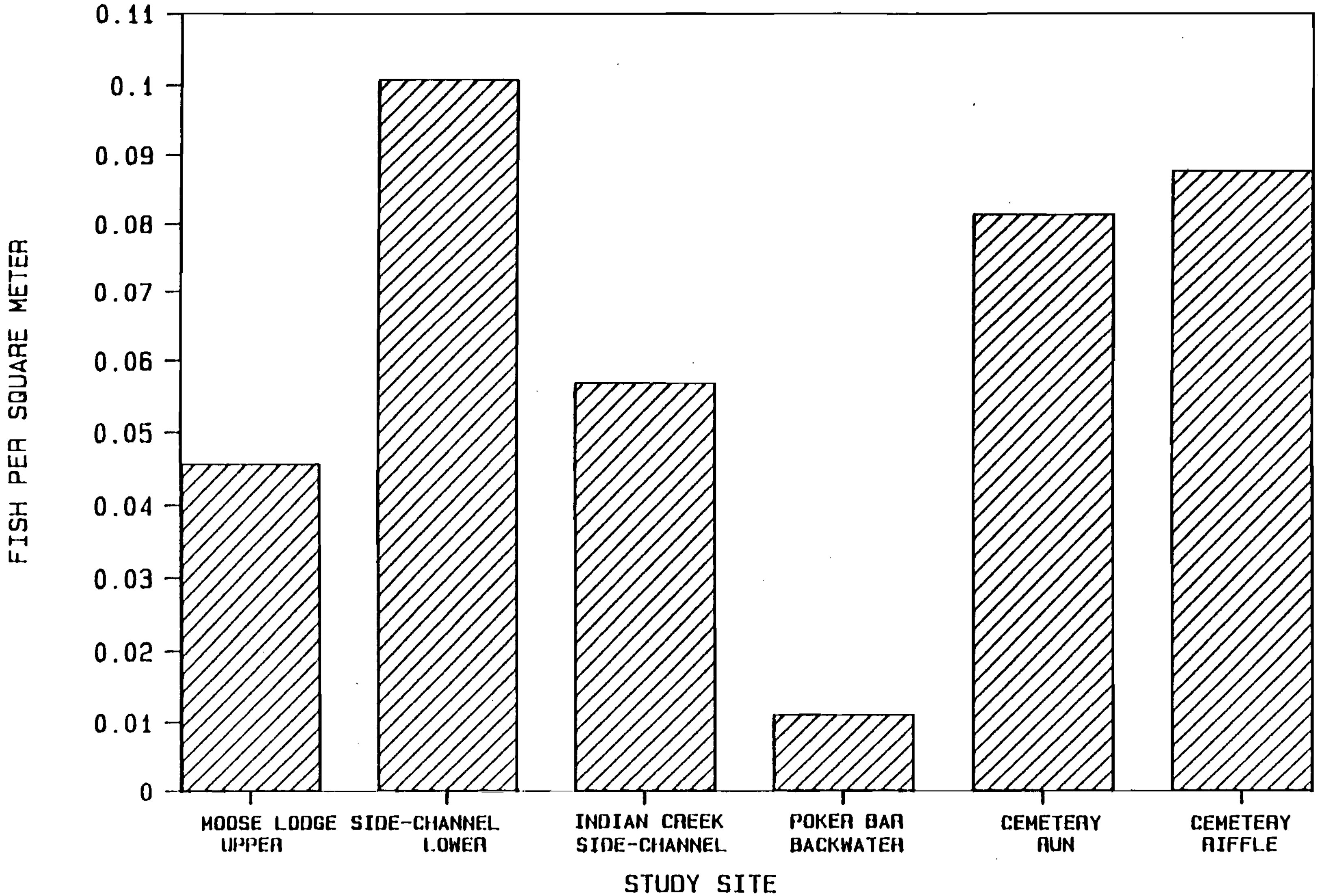


Figure 3. Densities of juvenile brown trout collected in six study sites located in the upper Trinity River, California 1988.

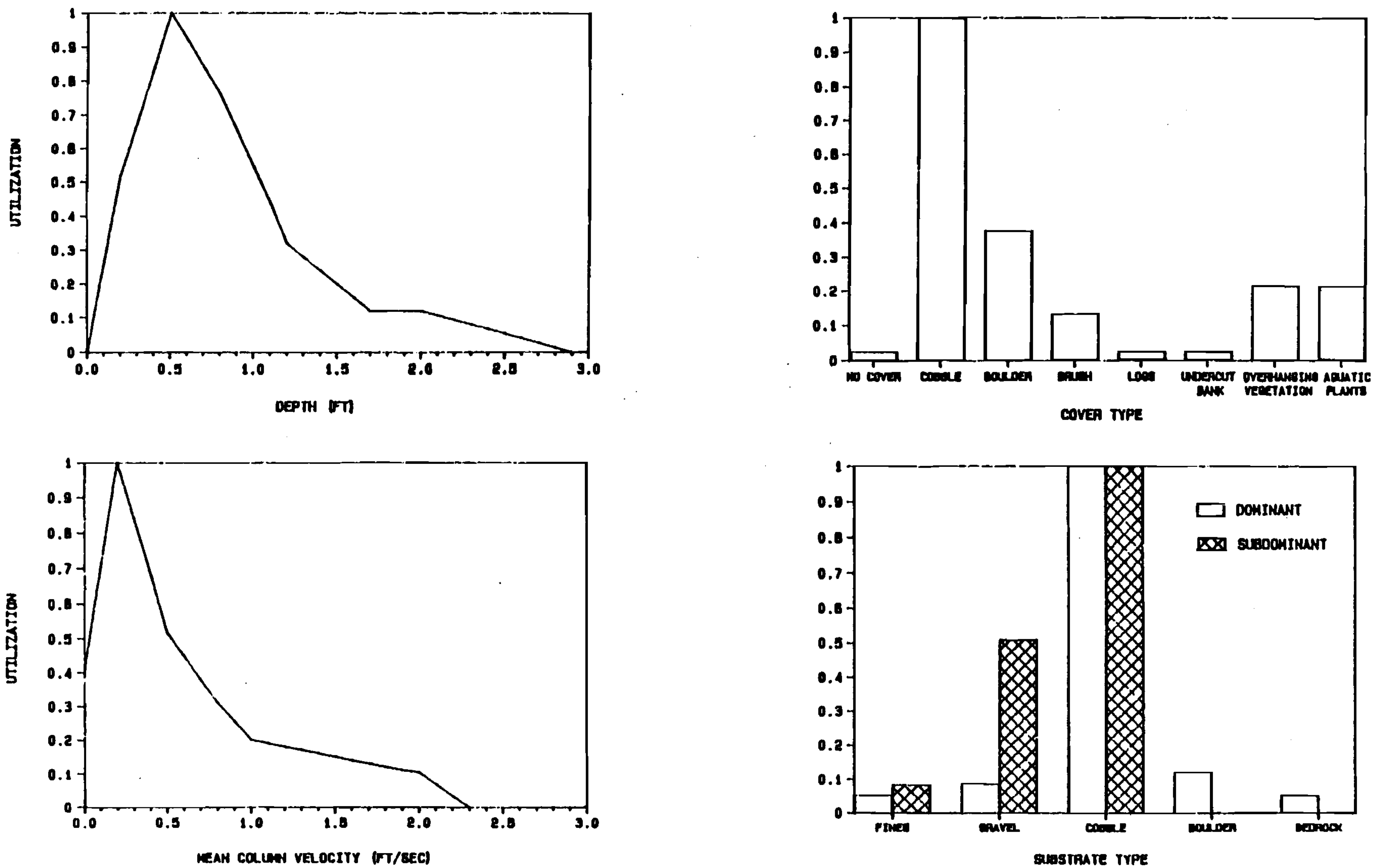


Figure 4. Habitat use by overwintering juvenile brown trout in the upper Trinity River, California 1988.

E-10 <u>Coho Salmon</u>. Coho salmon juveniles captured in the Moose Lodge side-channel ranged in fork length from 65 to 100 mm, with an average of 85 mm. Juvenile coho salmon were only captured in three study sites, lower Moose Lodge side-channel, Indian Creek side-channel and at Poker Bar backwater (Figure 5). The highest densities of juvenile coho salmon were observed in the lower section of the Moose Lodge side-channel. Although the highest densities for all species were found in this section, the microhabitats selected by coho salmon were quite different from those selected by juvenile steelhead and brown trout.

Coho salmon juveniles tended to select areas in still water with aquatic vegetation or woody debris as the main cover type (Figure 6). Juvenile coho were rarely observed holding underneath cobbles as was common behavior for juvenile steelhead and brown trout. In the backwater at Poker Bar all of the coho salmon captured were holding underneath one willow. This aggregative behavior was also observed while sampling mats of aquatic vegetation located in the Moose Lodge side-channel. Use of large woody debris by juvenile coho salmon would have probably been greater had this type of cover been available in greater quantities within the study sites or Trinity River in general.

<u>Chinook Salmon</u>. The large run of adult chinook salmon that entered the Trinity River during the spring and fall of 1987 produced millions of fry all along the Trinity River during the spring of 1988. Although most of these young emigrated from the system by early summer, some did remain in the Trinity River over the summer. Most of these late rearing chinook probably migrated downstream in the fall after lower river temperatures dropped. During our winter sampling we captured a total of 52 juvenile chinook salmon, some of which may have been of hatchery origin. In the Moose Lodge side-channel juvenile chinook salmon ranged in fork length from 65 to 99 mm, with an average of 78 mm.

Habitat utilization criteria were not developed for overwintering juvenile chinook salmon for two reasons: 1) not enough microhabitat observations were collected to accurately construct use criteria, and 2) overwintering behavior by juvenile chinook salmon is rare, and in this case there was no certainty as to the origin (wild or hatchery) of the juvenile chinook salmon captured.

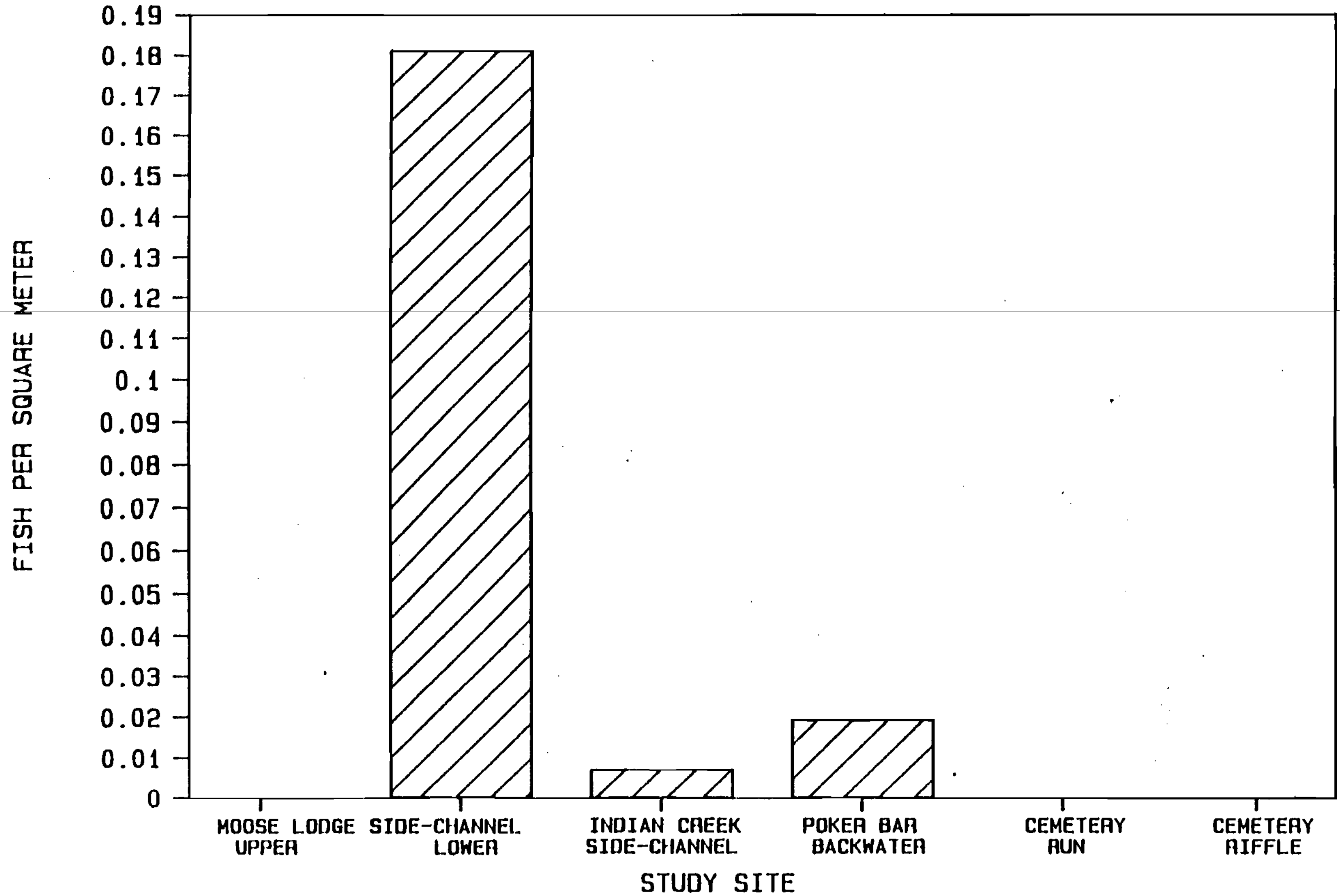


Figure 5. Densities of juvenile coho salmon collected in three study sites located in the upper Trinity River, California 1988.

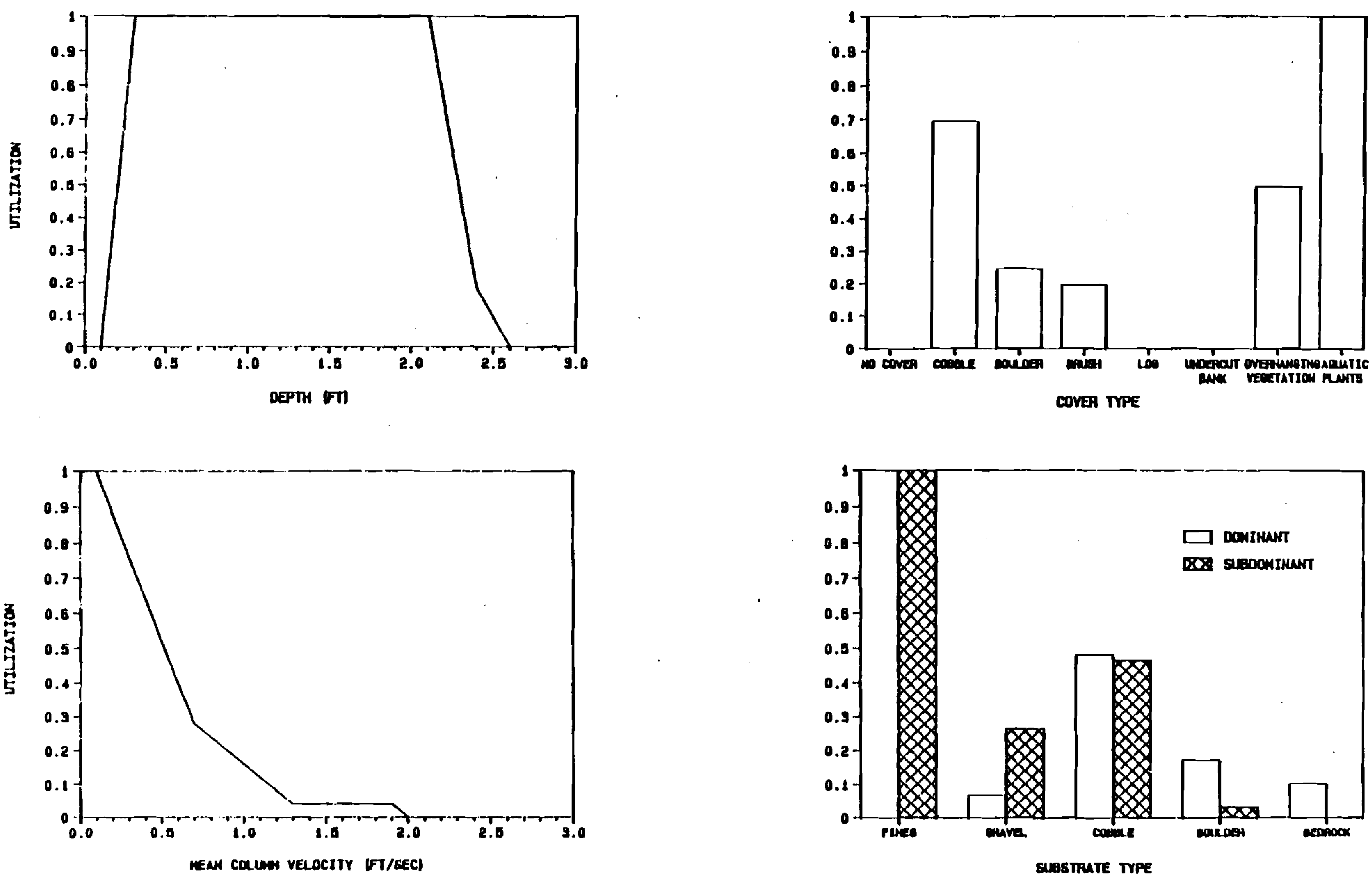


Figure 6. Habitat use by overwintering juvenile coho salmon in the upper Trinity River, California 1988.

DISCUSSION

The Moose Lodge side-channel, with cobble substrates and slow water velocities overwintered nearly four times more juvenile steelhead per habitat area than any of the other habitats sampled. The habitat use criteria developed for juvenile steelhead trout also show a strong preference for cobbles and slow water velocities as important variables in their selection of winter habitat.

Our findings, that steelhead fry and juveniles utilize cobble substrates extensively as refuge while overwintering, agree with those of Bjornn (1971), Bustard and Narver (1975a), Hartman (1965), and Swales et al. (1985). The intersticial spaces underneath and between cobbles provide young steelhead with refuge points in which to hold when environmental conditions are severe. Mason (1976) states that during periods of low temperature, salmonids have lower metabolism, reduced food requirements, and less swimming ability; thus, their survival depends more on areas of shelter and rest, than on food. By hiding in cobble substrates juvenile steelhead may avoid predation from surface feeding birds and mammals at a time when there swimming ability is reduced because of lower metabolic rates.

Coho salmon juveniles were only captured in the side-channel and backwater habitats. Although more coho were captured in the Moose Lodge side-channel than in either of the other two sites where coho where found, we think the reason for this was more of a function of coho salmon spawning distribution rather than habitat selection on the part of the juveniles. Since more coho salmon spawned in the upper river, near or within the Moose Lodge side-channel, more juveniles were present there than in the lower river sites near Poker Bar and Indian Creek, where few adult coho salmon spawn. This is in part borne out by the fact that even though cobbles are the dominant cover type available in the Moose Lodge side-channel, juvenile coho preferred to shelter inside clumps of aquatic vegetation or in woody debris. Coho salmon juveniles were rarely pulled from cobble substrates while electroshocking. This difference in cover type selection between juvenile coho salmon and steelhead trout was also observed by Hartman (1965) and Bustard and Narver (1975a). They state that steelhead fry and coho fry seek out different cover types in the winter, with coho associated with logs, roots, and bank cover areas and steelhead associated with rubble areas.

The habitat use criteria describing total depths used by all species may not be entirely appropriate. Since the microhabitat data collection was conducted with the use of a backpack electroshocker, the resulting depth criteria may be a better description of wading depth than actual fish preferences for those depths as discribed by the use criteria. This was an inherent problem with the sampling procedure that could not be avoided.

Historically, the Trinity River experienced many periods of high flows or freshets, which are still common in the tributary streams. High flows may still occasionally occur in the main stem Trinity River below Lewiston and Trinity Dams, as was evident during the February flood of 1986. These high flood flows undoubtedly cause mortalities to overwintering salmonids through displacement downstream or by crushing them under moving bedload. In the spring of 1986, immediatly after the flood in February, we noticed several juvenile steelhead in the lower Trinity River that had been injured, probably from being caught between moving cobbles and sand during the high water. Therefore, it seems evident that cobbles alone do not provide sufficient wintering habitat for juvenile steelhead.

Wintering habitat must also provide areas that are sheltered from high velocities that may cause scouring of bedload material. side-channels, backwaters, and deep pools may all provide velocity shelters required by overwintering steelhead. Pools, however, are probably not optimum overwintering habitats in the Trinity River because of the large amounts of sand that are deposited within them as flows drop. Deposition of new sand within these pools could trap the young steelhead hiding under existing cobbles should they fail to move. Natural pools are also formed and reformed by scour during peak flows which would definitely have adverse effects on juvenile steelhead holding within them. side-channels are less affected by high flows, since they are generally located across the inside bends of the river where velocities are reduced during high flows. side-channels are also bordered by healthy riparian systems which reduce velocities when flood flows do occur.

The quantity and quality of suitable winter habitat within the Trinity River is extremely low. The same habitat problems that have reduced salmon and trout spawning and summer rearing habitat in the river have also nearly eliminated crucial overwintering habitat for juvenile steelhead and brown trout and coho salmon. Excessive sedimentation of substrates by granitic sand has eliminated the intersticial areas required by young trout seeking refuge from high flow and predation during the winter months. Channelization of the mainstem Trinity River above the North Fork Trinity River has reduced surface area and increased velocities due to the changed morphology of the channel. Currently, when high flows do occur a greater percentage of the water is forced to remain within the channel rather than spread out across bars or through secondary channels as would have happened historically. This phenomenon has probably reduced the amount of slow velocity habitats that existed before constuction of the Trinity River Division.

It is important that future restoration efforts within the

Trinity River consider the value of overwintering habitat when considering projects directed toward increasing production of juvenile steelhead trout and coho salmon. Without such consideration, increases in production in other areas of habitat work, such as improving spawning habitat, could all be for naught should the limiting factor on smolt production turn out to be winter habitat survival (Hall and Baker, 1982).

Additional information, which is important the effective management and habitat restoration for these species,is the knowledge of survival rates for each year class over the winter season. This type of information may verify the importance of winter habitat as a factor contributing toward over all steelhead trout and coho salmon smolt production.

APPENDIX F

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION

1989

U.S. Fish and Wildlife Service
Fish and Wildlife Enhancement
Sacramento Field Office
2800 Cottage Way, Rm. E-1803
Sacramento, California 95825

Prepared by
the Staff of

The Trinity River Flow Evaluation
P.O. Box 630
Lewiston, California 96052

HABITAT REQUIREMENTS FOR JUVENILE CHINOOK

INTRODUCTION

The Trinity River Flow Evaluation is composed of six major study tasks. Task 3 of the study is composed of two objectives: 1) To determine the amount of salmon and steelhead habitat available in the Trinity River under various flow conditions and the various levels of habitat rehabilitation that may be achieved either through the Trinity River Basin Fish & Wildlife Management Program or through other resource actions, 2) To determine the amount of habitat required for each salmon and steelhead life-stage to sustain those portions of fish populations in the Trinity Basin that were historically dependent on the Trinity River downstream of Lewiston Dam.

Currently, in order to determine fish population levels that the Trinity River is capable of supporting, weighted usable area estimates are multiplied by fish densities for a certain species and lifestage that have been described under Task 4 (studies of fish populations and life history characteristics). The implied assumptions are that observed fish densities correspond to or are obtained under conditions of maximum carrying capacity, and that multiplication of these fish densities by weighted usable area result in a direct relationship between actual fish abundance and weighted usable area estimates.

The goal of this study is to validate habitat use of transect cells as predicted by IFIM weighted usable area estimates, and to determine if a relationship between observed fish densities and cell joint preference factors exists. Should a direct relationship between fish density and predicted suitability from joint preference factors be found, an estimate of the total standing crop can be determined by multiplying total WUA by the maximum estimated fish density (95% CI) observed for cells with an equivalent suitability of 1.0.

Juvenile chinook salmon were selected as our evaluation species for two reasons: 1) we felt they would be the most likely species to meet the assumption of carrying capacity since 47,169 natural spawning chinook salmon were estimated in the Trinity River above Willow Creek in 1988 (CDF&G, 1988) providing for a large recruitment of naturally produced fry in 1989, and 2) chinook salmon juveniles have the shortest freshwater lifestage, therefore biological impacts which may influence the population may be less severe than those which may be expected to effect other species which rear for one or more years. Thus, physical habitat parameters may reasonably be assumed to be the primary factor affecting carrying capacity for this lifestage.

STUDY SITE

We originally planned to sample five study sites between Lewiston and the confluence of the North Fork Trinity River, however, heavy rain and snow storms during March 1989 delayed our sampling until April. High river flows and turbid water conditions prevented us from sampling study sites located downstream of Lewiston. Therefore, effort was concentrated in the Cemetery study site located three river miles below Lewiston Dam. A description of the Cemetery study site may be found in our 1986 annual report (USFWS, 1986).

Thirteen IFIM transects have been monitored within the Cemetery study site since 1986. Of these, five transects were selected for this evaluation on the basis of habitat type. Transect 1 represents habitat typical of upper river runs. The majority of depths across the transect range between 2 and 3.5 feet and mean column velocities were less than 3 cubic feet per second. The substrates across transect 1 range from small boulders to gravel from right to left. Transect 2 is located across a riffle with cobble substrates. The total depths are less than 2.5 feet with mean column velocities ranging up to 4.5 feet per second. Transect 3 contains two chutes with backwaters located along the river edges. Mean column water velocities exceed 5 cubic feet per second in the left chute. The right and left edges of this transect contain cobbles and small boulders. Bedrock is located underneath both chutes and sand is the primary substrate present in the quiet water area between the two chutes. Transect 7 is located across the bottom of a riffle at the upstream end of Sawmill Pool. A backwater and sandy ledge is present along the right bank. Across the thalweg substrates are composed of large cobbles embedded in approximately 10 to 30 percent sand. Transect 9 is located across the lower half of Sawmill Pool. The total depth is slightly over 6 feet and mean column velocities were less than 2 feet per second. The right bank is formed by bedrock ledges which change to cobbles across the thalweg. A gravel bar forms the left bank of the transect.

METHODS

IFIM field data was collected following those procedures recommended by the U.S. Fish & Wildlife Service's, National Ecology Research Center's, Aquatic Systems Branch (Bovee and Milhous, 1978; Trihey and Wegner, 1981). Water depths were measured with a top setting wading rod and mean column velocities were measured with a Price AA current meter. Water surface elevations were measured with a spirit level and fiberglass level rod from established benchmarks with an assumed elevation of 100.00. Distances and vertical locations were measured with a surveyor's rope which was zeroed on iron head pins. Hydraulic field data was collected on April 7, at a river discharge 300 cubic feet per second.

The resulting field data was constructed into IFG-4 input decks and run through the USFWS's microcomputer IFG-4 and HABTAT programs. The habitat preference criteria utilized in the HABTAT program were developed using direct observation techniques on the Trinity River by Hampton (1988). Simulated mean column velocities and water depths for each transect were obtained by examination of the calibration details provided by the IFG-4 program output with IOC option 2 set on. Individual transect cell suitability estimates were obtained from the HABTAT program with IOC option 13 turned on. The resulting information was then combined and analyzed on micro-computer spreadsheet software for easy comparison.

In order to assist field data collection of fish use, painted cobbles were placed across each transect during IFIM field data collection to denote IFIM cell boundaries. In order to simplify accurate identification of cells by snorkel divers, vertical distances (ft) were written on each cobble with an indelible marker.

Fish utilization across each transect was determined by snorkel divers as follows. At the beginning of each sample day ropes were strung tight across each transect with the aid of ascenders, carabiners, and pulleys. After allowing the ropes to rest for at least an hour, one diver would cautiously approach the rope from downstream and attach an additional pulley and tag line. The diver would then use the pulley and tag line to slowly ferry across the transect, while maintaining a distance of approximately 6 feet downstream from the transect. The divers controlled movement across each transect by slowly angling his body in either direction. The snorkel diver would then count the number of juvenile chinook salmon located within each cell as denoted by the white cobble markers. Fish numbers were recorded on underwater slates. Observations were generally made between 1:00 and 4:00 pm. On April 12 we conducted one set of observations between 9:30 and 11:00 am.

Fish densities were calculated for each cell by dividing the average number of fish observed by the cell area sampled. The cell area was determined by multiplying the cell width by the observational cell length (6 ft). The observed fish densities were then paired with their corresponding joint preference factors and sorted in ascending order. Joint preference factors were then organized into 0.05 intervals and their corresponding fish densities were averaged within these interval widths. A linear regression was then calculated between cell joint preference factors and average observed juvenile chinook salmon densities. Stat-Pak statistical software was used to obtain the results of the regression equation and 95% confidence intervals about the regression line.

RESULTS

A total of thirteen fish sample observations were completed between April 6 and April 19, 1989. River flows throughout the sampling effort were maintained at 300 cubic feet per second. Figures 1 through 5 present study transect profiles , as predicted by the IFG-4 program, predicted cell joint preference factors from the HABTAT program output, and the average juvenile chinook salmon densities that were observed for each cell.

A regression analysis of average juvenile chinook salmon density on cell joint preference factors is presented in Figure 6. The resulting regression equation is as follows:

$$Y = 4.881968E-02 + 0.43043 * X$$

where, **X = Predicted cell joint preference factor**
Y = Estimated juvenile chinook salmon density (fish/ft^2)
r^2 = 0.6637

Based on these results, optimum habitat, that is habitat cells with a joint preference factor of 1.0, should contain 0.48 juvenile chinook salmon per square feet. Habitat cells with a joint preference factor of 0.0 should contain 0.05 juvenile chinook salmon per square feet.

DISCUSSION

The development of a relationship between habitat quality as predicted by IFIM and juvenile chinook salmon densities brings us one step further in our quest to develop habitat ratios that may be used to accurately identify factors limiting chinook salmon production within the Trinity River. Although these results increase our confidence in the Instream Flow Incremental Methodology as being the best approach to use in our situation there are some aspects of our findings that require additional discussion.

During our field observations on juvenile chinook salmon we noted four parameters that include both behavioral and physical aspects that affected our final results.

The HABTAT program predicted joint preference factors ranging from 0.45 to 0.76 for the habitat cells located between verticals 93 and 116.5 on transect 2 (Figure 2). However, juvenile chinook salmon were rarely observed in these habitat cells. While conducting our observations of this area we consistently observed juvenile steelhead trout, which leads us to postulate that the predatory behavior of the steelhead within these habitat cells probably deterred juvenile chinook salmon from entering this area. This was the only instance within our sample sites that

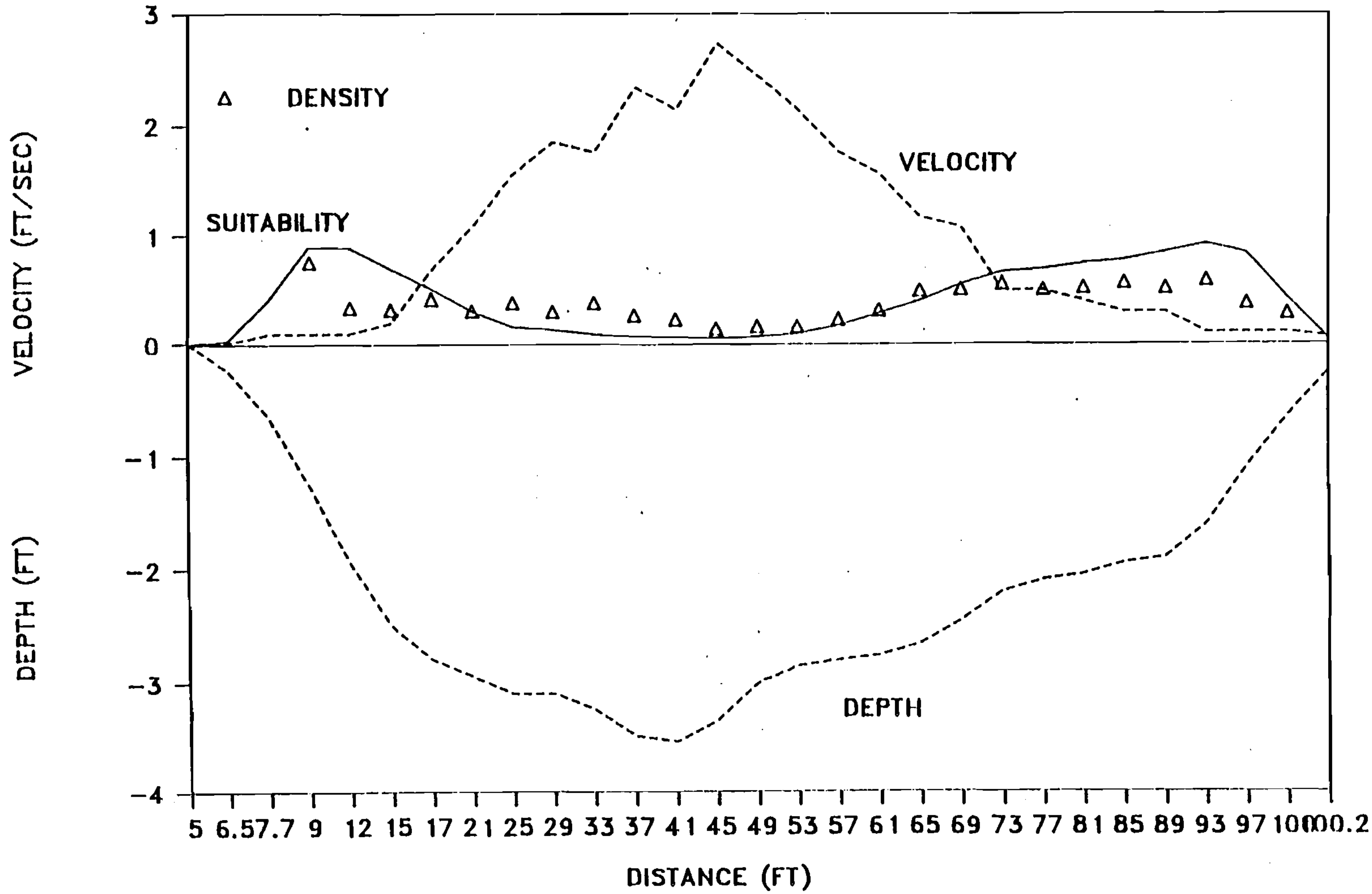


Figure 1. Profile of transect 1 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

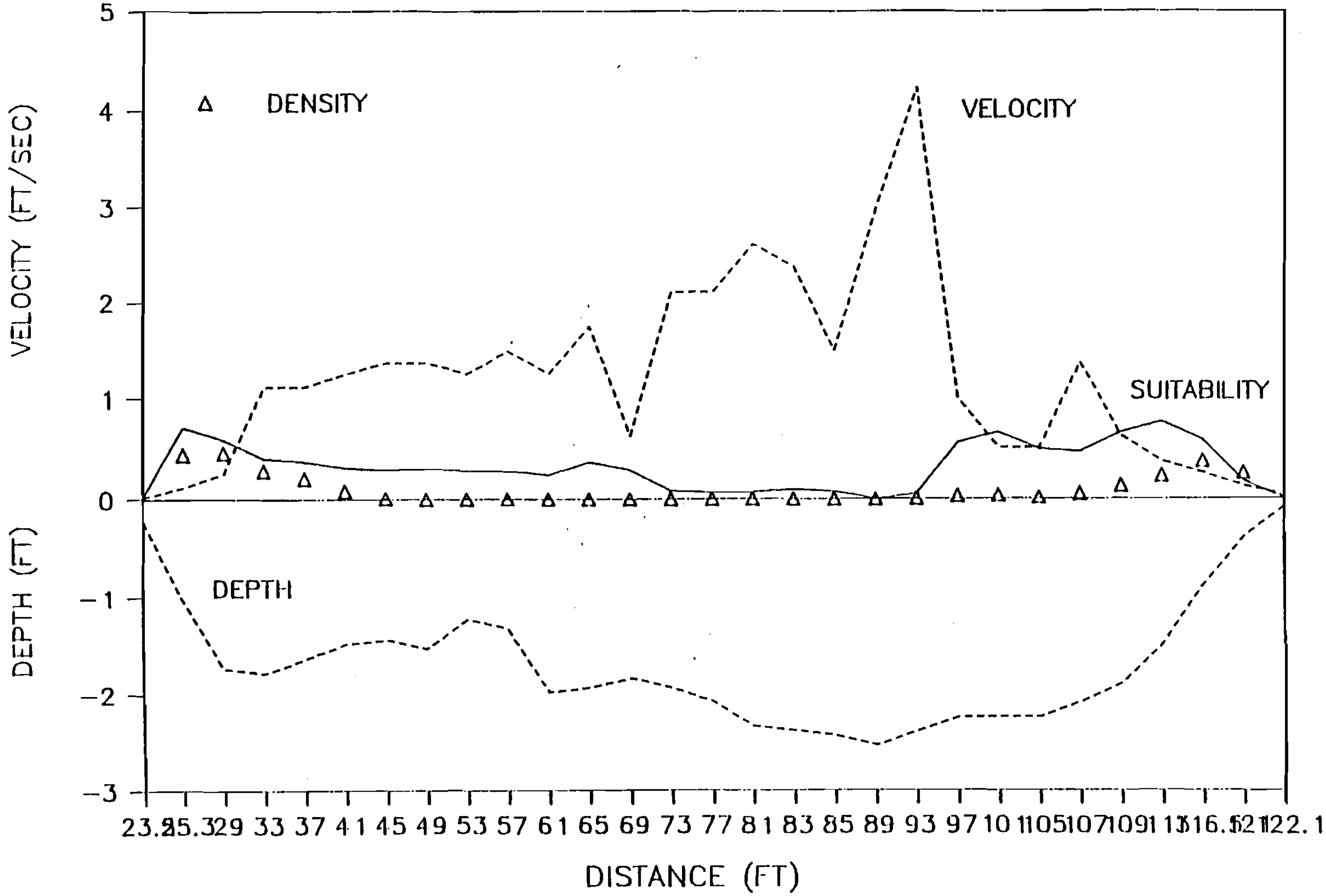


Figure 2. Profile of transect 2 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

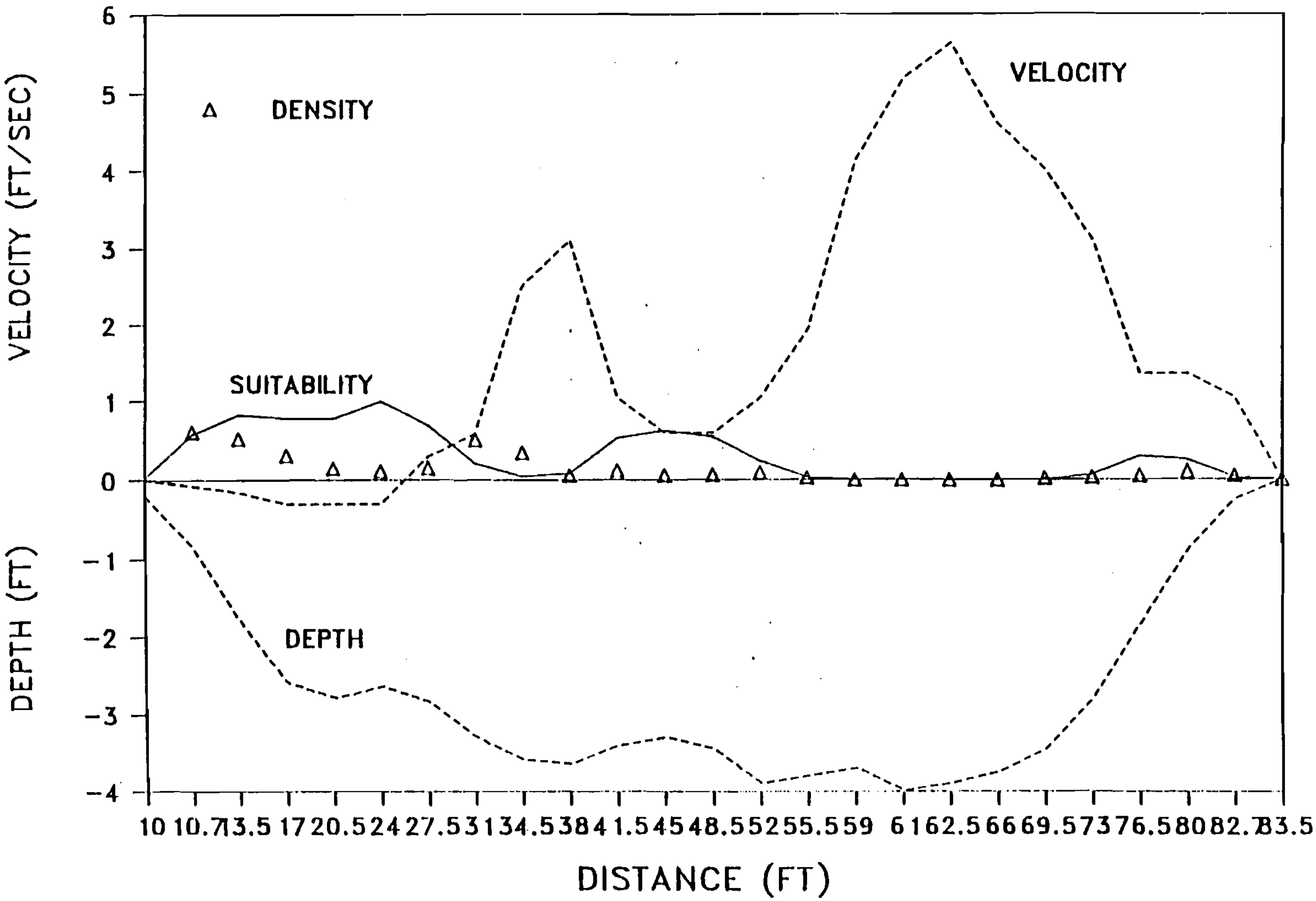


Figure 3. Profile of transect 3 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

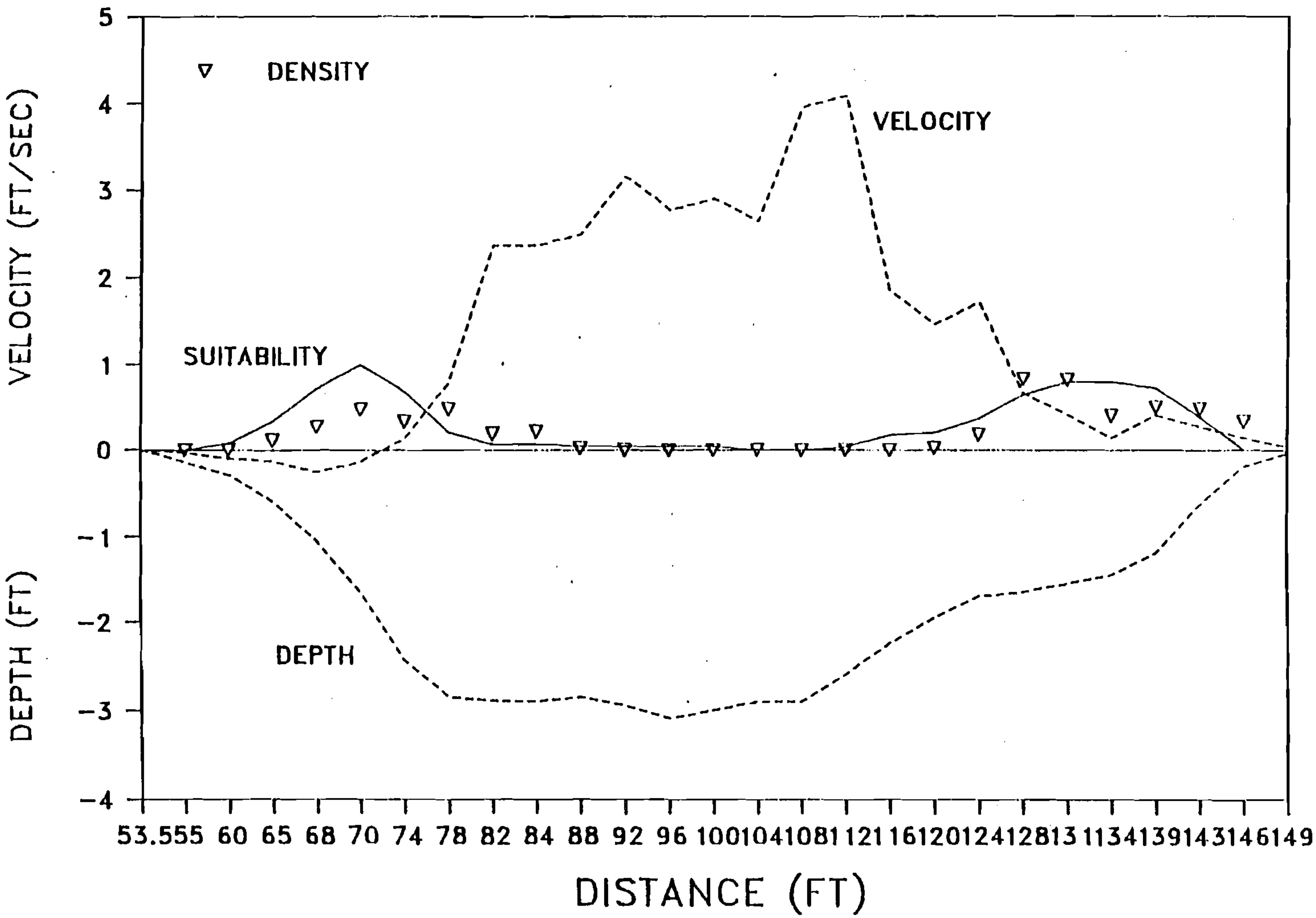


Figure 4. Profile of transect 7 showing the observed densities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

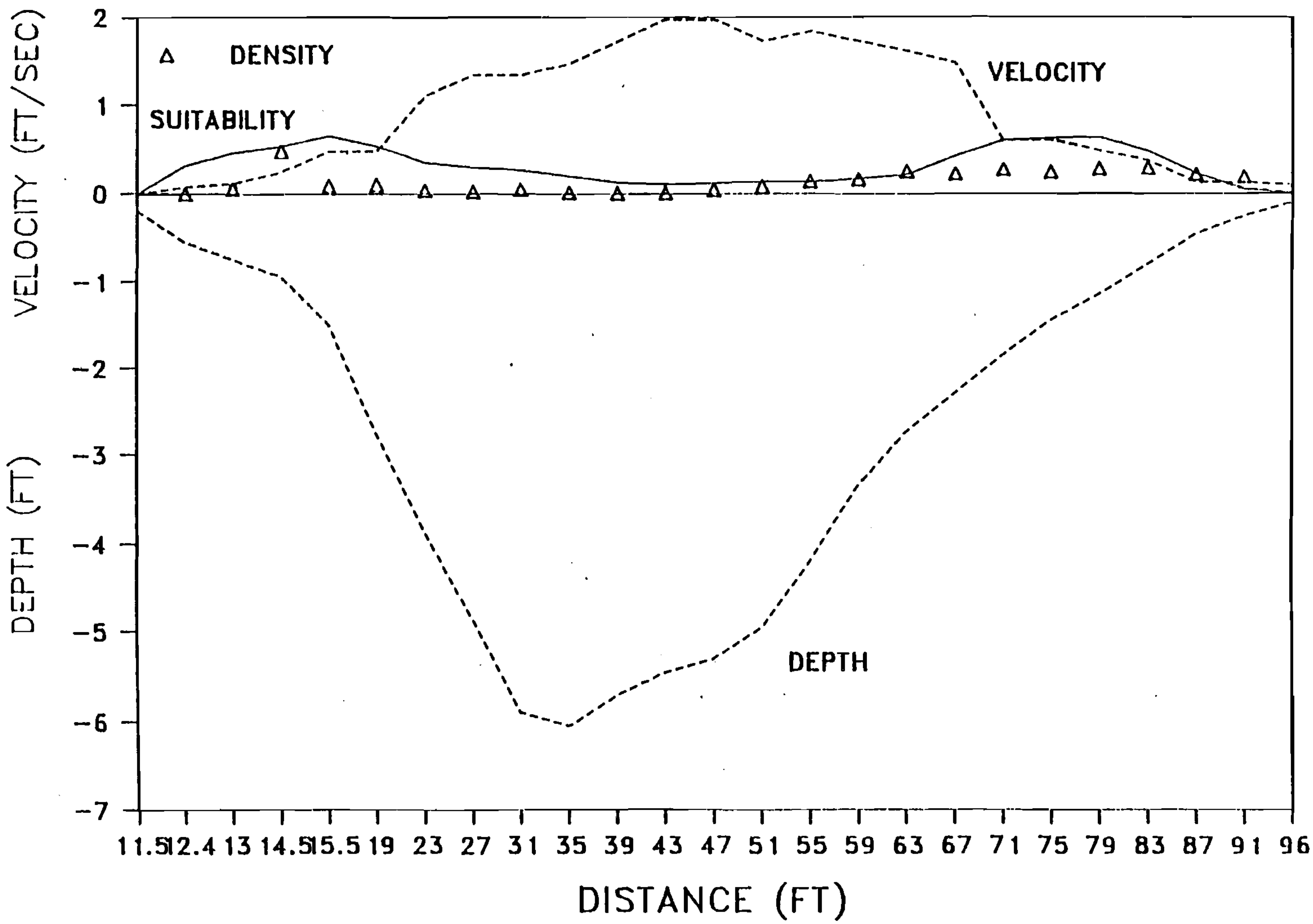


Figure 5. Profile of transect 9 showing the observed denisities of juvenile chinook salmon per cell in association with the habitat suitabilities predicted for each cell by the HABTAT program.

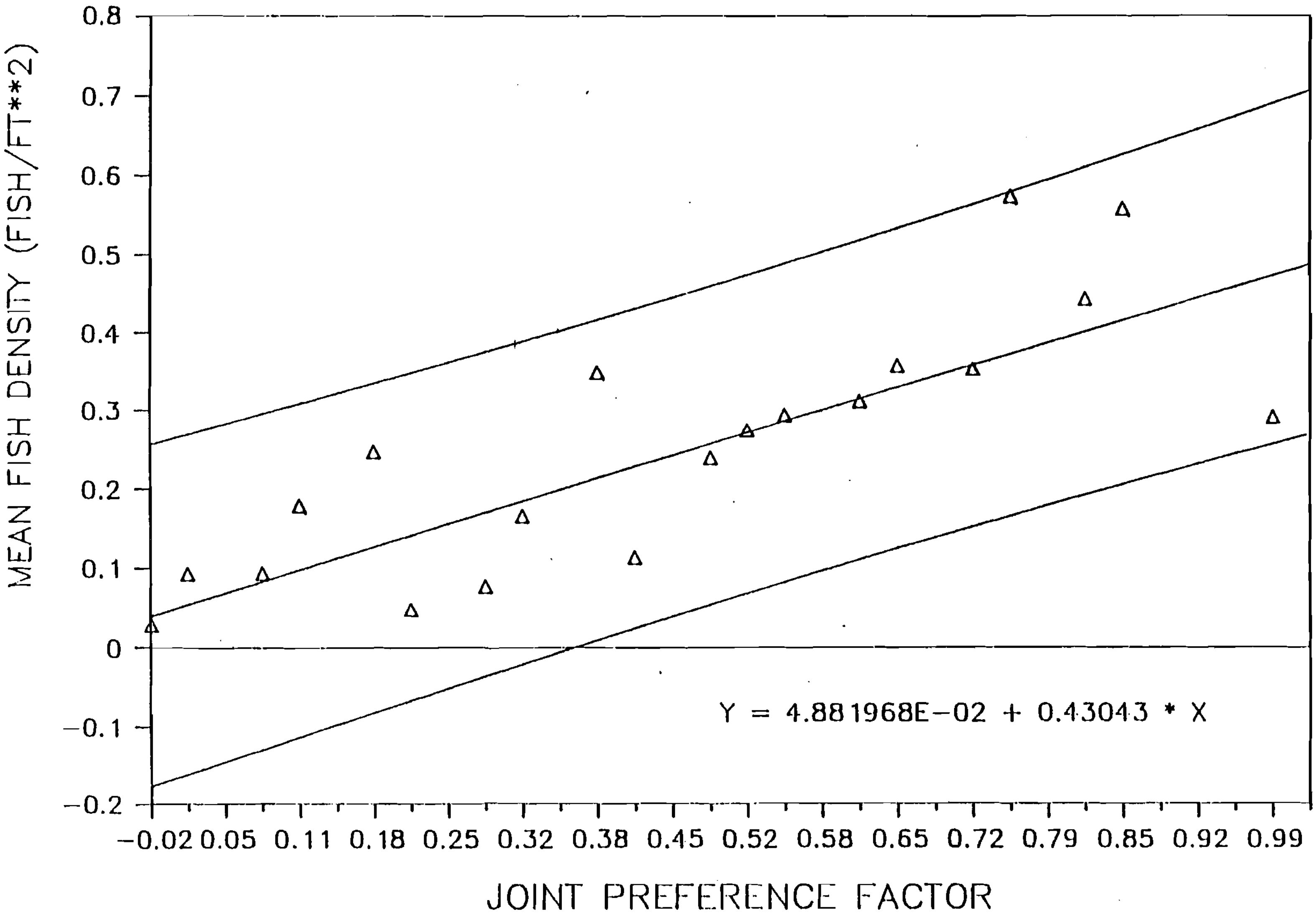


Figure 6. Regression analysis between average juvenile chinook salmon densities and joint preference factors predicted by the HABTAT program.

interspecies behavior seemed to affect habitat use by juvenile chinook salmon.

During the habitat preference study we found that juvenile chinook salmon selected different microhabitats at different hours or the day. At night juvenile chinook salmon tended to congregate in slow or still water areas in close proximity to substrates or cover items adjacent to the river edges (Hampton, 1988). During daylight hours juvenile chinook salmon moved out into faster water areas away from the bank. This behavior trait was also observed during this study on April 12 when we sampled each transect four times, twice in the morning starting at 9:30 am and twice in the afternoon starting at 1:30 pm. During the afternoon observations we noticed that juvenile chinook salmon had distributed into habitat cells that were vacant during the morning observations. It appears that changes in habitat selection from preferred evening microhabitats to preferred afternoon microhabitats occur gradually throughout the daylight hours. Therefore, saturation of all available microhabitats probably isn't complete until late afternoon. This behavioral trait should be considered in future habitat preference criteria work if the full range of utilized rearing habitat is to be effectively measured.

The highest densities of juvenile chinook salmon that were observed during our study occurred in cells that contained less than optimum habitat as predicted by HABTAT program output joint preference factors, yet were adjacent to shear velocity zones. For example, the habitat cell located at 126 feet on transect 7 (Figure 4) received a joint preference factor of 0.648, yet the observed density of juvenile chinook salmon using this cell was 0.826 and was the highest density calculated for all habitat cells. The mean column velocity modeled for the vertical at 124 feet was 1.72 feet/second and the mean column velocity modeled for the vertical located at 128 feet equalled 0.66 feet/second. Therefore, the predicted mean column velocity for the habitat cell itself equaled 1.19 feet/second when in actuality the majority of cell contains water velocities less than 1.0 feet/second. Slower water velocities would of resulted in a higher joint preference factor for the habitat cell thus yielding a better fish density/joint preference factor relationship. The shear zone present at vertical 124 provided a good feeding lane for juvenile chinook salmon located in the habitat cell. This problem could have been corrected by establishing smaller habitat cells during IFIM data collection.

Another velocity shear zone sampled with similar characteristics is located between habitat cells at 76 and 80 feet. In the habitat cell located at 76 feet we observed 0.47 juvenile chinook salmon per square feet. The HABTAT program predicted a joint preference factor of 0.195 for the same habitat cell. The water velocity predictions made by the IFG-4 program for the verticals located at 74, 78, and 82 feet were 0.13, 0.79, and 2.38 feet/second respectively. The velocity shear zone is located in the habitat cell at 80 feet adjacent to the habitat cell located at 76 feet where high juvenile chinook salmon densities were found.

These findings suggest that the current habitat preference criteria developed for juvenile chinook salmon may need further refinement in order to better reflect current habitat use. Chinook salmon escapement to the Trinity River in 1984 and 1985 equaled 5,654 and 9,217 adults above Willow Creek. The majority of habitat preference data for juvenile chinook salmon was collected in 1985 and 1986, which would have been fry produced by the 1984 and 1985 spawners. In 1986, 1987 and 1988 chinook salmon spawing escapements have equaled 92,548, 71,920 and 44,616 adults respectively. Since completion of the habitat preference study fry and juvenile chinook salmon densities have been much higher and the extent of habitats used by young chinook salmon has probably increased habitats near saturation. It seems apparent that during our habitat preference data collection period the habitat was underseeded, resulting in criteria that may not include all microhabitats used by juvenile chinook salmon. This spring we intend to direct more effort to increasing our habitat use data base as well as obtain additional information regarding fish densities in relation to WUA.

The same velocity shear zones that produce optimum rearing habitat for juvenile chinook salmon may in some cases isolate midstream habitat from juvenile chinook salmon. For example, on transect 3 the HABTAT program predicted that three habitat cells with joint preference factors of 0.533, 0.622, and 0.533 were located at 39.75, 43.25, and 46.75 feet respectively. However, the observed densities of juvenile chinook salmon within these three habitat cells were 0.124, 0.058, and 0.062 fish per square feet. Based on the regression equation presented here we would expect to find juvenile chinook salmon densities for these three habitat cells to equal 0.27, 0.31, and 0.27 fish per square feet. The presence of high velocity zones on both sides of these habitat cells restricted movement of juvenile chinook salmon from either bank, thus preventing these habitat cells from reaching their full potential. Future habitat restoration projects that seek to increase juvenile chinook salmon habitat in swift water areas should keep these considerations in mind.

APPENDIX G

ANNUAL REPORT

TRINITY RIVER FLOW EVALUATION

1991

U.S. Fish and Wildlife Service
Fish and Wildlife Enhancement
Sacramento Field Office
2800 Cottage Way, Room E-1803
Sacramento, California 95825

Prepared by
the Staff of

The Trinity River Flow Evaluation
P.O. Box 630
Lewiston, California 96052

COMPARISON OF WUA AND DENSITIES OF JUVENILE CHINOOK SALMON

INTRODUCTION

The Trinity River Flow Evaluation uses the Instream Flow Incremental Methodology (IFIM) to evaluate the effects of flow and habitat restoration activities on anadromous salmonid habitat. The IFIM can be thought of as a collection of computer models and analytical procedures designed to predict changes in fish habitat due to increments of flow change (Bovee 1982). As part of the IFIM, the Physical Habitat Simulation system (PHABSIM) links macrohabitat measurements, or predictions, in terms of channel structure and discharge, with a species microhabitat suitability, described in terms of depth, velocity, and a channel index such as cover or substrate, to estimate the total habitat or weighted usable area (WUA) available for a species life stage. A basic assumption of the IFIM is that by optimizing the quantity and quality of available microhabitat (WUA), a beneficial response in fishery populations will result.

In a survey concerning instream flow issues, one of the most commonly reported needs for instream flow research included testing of the relationship between flow, habitat, and fish production (Reiser et al. 1989). Intuitively, it seems logical that those microhabitats where a species lifestage is most frequently observed, those most suitable, would also support the greatest densities of that species lifestage. However, verification of the relationship between WUA and fish standing crop has proven to be a difficult task (Scott and Shirvell 1987; Conder and Annear 1987; Orth and Maughan 1982; Wolff et al. 1990). Factors that may complicate the verification of the relationship between WUA and fish biomass include interspecies competition, predation, food availability, harvest, and short duration habitat limiting events such as flood flows or stream dewatering (Orth 1987).

In California, there has been considerable effort on the part of various investigators to develop salmonid population models (Hagar et al. 1988, EA Engineering, Science, and Technology, Incorporated 1991, and Cheslak and Jacobson 1990). In 1990, the National Ecology Research Center initiated efforts to develop a population model that will link existing habitat and stream temperature models to predict production of chinook salmon presmolts from the upper Trinity River. The development of a population response model on the Trinity River will improve our ability to conduct limiting factor analysis, evaluate habitat restoration projects, and generate more effective flow recommendations to optimize fishery populations.

Calibration and verification of any IFIM based population model for anadromous salmonids will require that the relationship between WUA and standing crop be described for each freshwater lifestage. For the last three years the Trinity River Flow Evaluation has been attempting to describe habitat-fish density relationships for early life stages of anadromous salmonids. In our side channel evaluations we described relationships linking mesohabitat quality with fry and juvenile chinook salmon standing crop (USFWS 1990). In 1989 we concentrated our efforts on trying to describe the relationship between the predicted composite suitability index for individual habitat cells and use of habitat cells by juvenile chinook salmon (USFWS 1989). When the National Ecology Research Center selected the Trinity River as one of two sites to develop an IFIM based population model, we concentrated our efforts in the spring of 1991 on further describing the relationship between habitat availability and habitat use of juvenile chinook salmon.

METHODS

Fifteen transects were sampled within four study sites along the upper Trinity River at Cemetery (RM 109), Bucktail (RM 105), Poker Bar (RM 102) and Steel Bridge (RM 99). Field data was collected following the procedures recommended by the U.S. Fish & Wildlife Service (Bovee and Milhous, 1978). Distance to vertical sampling locations were measured with a tape from established iron head pins. Total depths were measured with a top setting wading rod and mean column velocities were measured with a Price AA current meter.

Computation of Weighted Usable Area

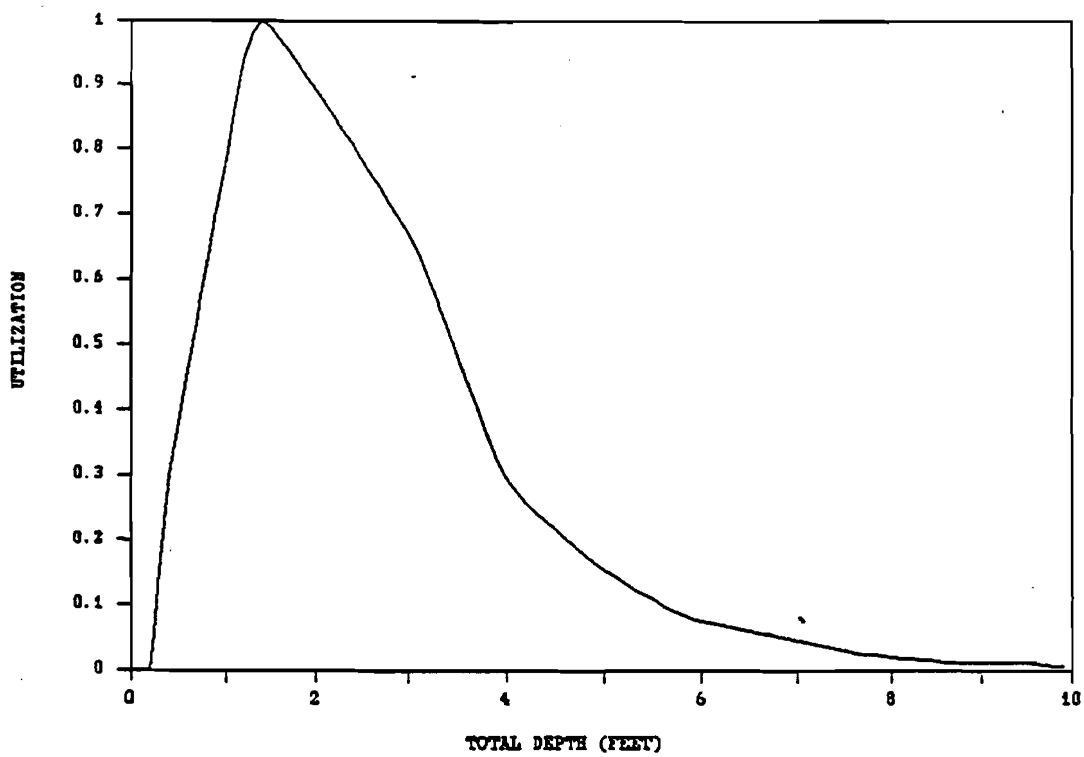
Because of stable flow conditions, hydraulic models were not used to simulate depth and velocity values across each transect. To calculate WUA, we multiplied actual field data by habitat use criteria. This was done using procedures similar to the PHABSIM system. The total depth and mean column velocity for each habitat cell was calculated by averaging the measured depth and mean column velocity of adjacent verticals. The composite suitability index for each cell was then calculated by multiplying the habitat cell depth and mean column velocity by habitat use criteria. The habitat utilization criteria used to calculate the composite suitability index were developed by Hampton (1988) using direct observation on the Trinity River (Figure 1). Only depth and mean column velocity criteria were used in the calculation of the composite suitability index. No channel index values (substrate or cover) were used. Cell Weighted Usable Areas were then determined by multiplying the Composite Suitability Index by the cell area. The total WUA for each mesohabitat equaled the sum of the cell WUAs across the transect.

So that we could visually inspect the entire microhabitat cell during underwater observations, all cells were limited to 6 feet in length. Cells ranged in area between 12 and 42 square feet. The corners of each habitat cell were marked with numbered white cobbles so that they could be easily located and identified by underwater observers.

Direct Observation Techniques

Across each transect, juvenile chinook salmon use was determined by snorkel divers. Each day, prior to sampling, ropes were strung across each transect approximately three to four feet above the water surface. After allowing the ropes to rest undisturbed for a minimum of 30 minutes, one diver would cautiously approach the line from downstream and attach a pulley and hand line. The diver would then use the hand line to suspend downstream from the transect to observe fish within habitat cells (Figure 2). The divers controlled movement across the transect by slowly angling their bodies against the current. The number of juvenile chinook salmon in each cell was then counted and recorded on an underwater slate. Each transect within the study site was sampled once by each diver each sampling day. In 1991 all sampling was conducted after 12:00 noon to coincide with peak activity levels of juvenile chinook salmon and insure full use of all available microhabitats (USFWS 1989).

Observations of fish use were made between 6 April and 19 April of 1989 and between 1 May and 23 May of 1991. In 1989, we sampled five transects at the Cemetery study site on eleven occasions for a total of 55 transect counts. In 1991, we sampled four transects at Cemetery study site, four transects at Bucktail study site, three transects at Poker Bar study site, and four transects at Steel Bridge study site. With the exception of the Cemetery study site, all transects were sampled on four occasions for a total of 54 transect counts.



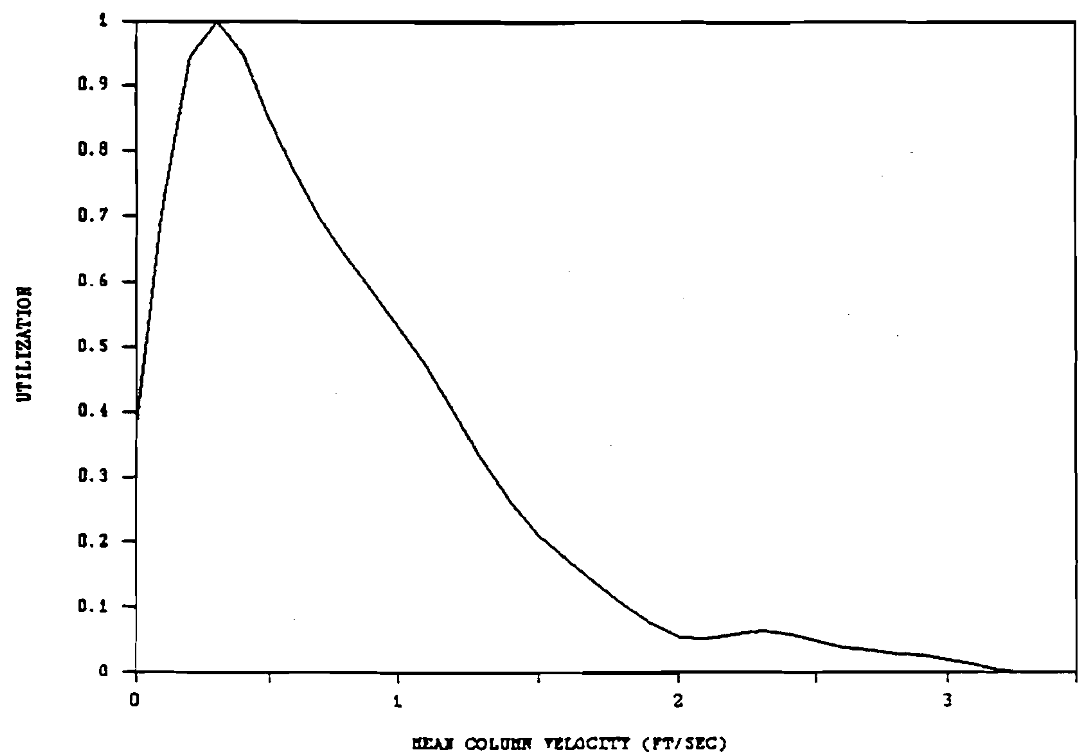


Figure 1. Habitat use criteria for juvenile chinook salmon in the Trinity River.

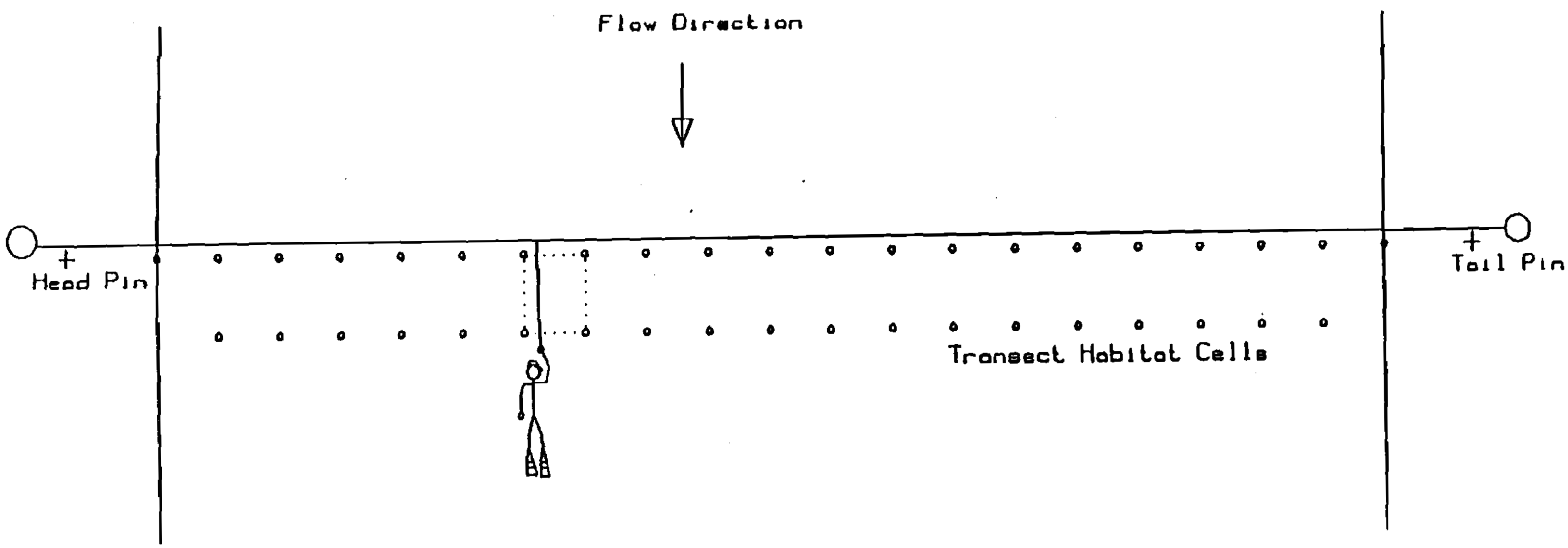


Figure 2. Top view of 'Tinkerbell' line transect sampling method used to conduct observations of juvenile chinook salmon habitat use across IFIM transects in the upper Trinity River.

Microhabitat Data Analysis

Observed densities of juvenile chinook salmon were paired with their respective microhabitat cell. All habitat cells were then sorted based on the amount of weighted usable area calculated for each cell. Sturges' Rule (Sturges 1926) was then used to determine the optimum interval size to place calculated cell weighted useable areas. Mean densities of juvenile chinook salmon and 95% confidence intervals were determined for each interval. To determine if cell WUA had an influence on fish density, a regression analysis was conducted between mean fish density and cell weighted usable area.

In order to compare our finding in 1991 with data collected in 1989, the 1989 data were analyzed using the methods described here. Data collection procedures were the same in both years.

RESULTS

Diver Precision

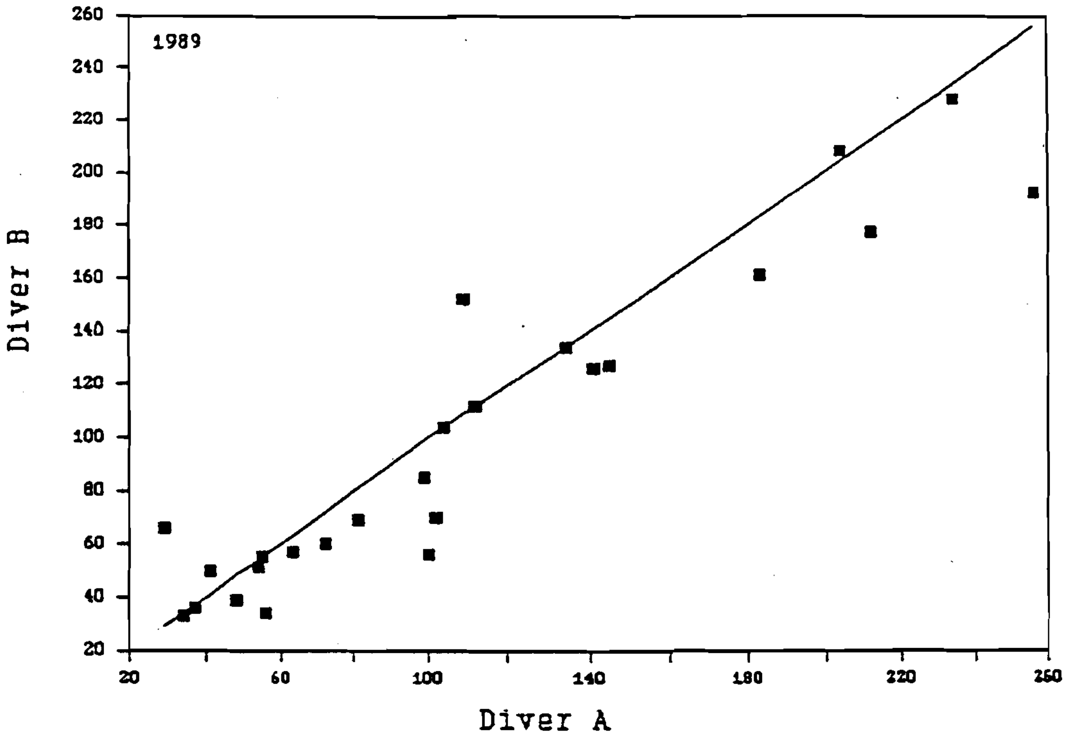
Juvenile chinook salmon proved to be an ideal candidate for this type of validation study because they were relatively abundant and were rarely frightened or disturbed by snorkel divers. When fish were disturbed, we found that in most cases, if the diver remained motionless, juvenile chinook redistributed themselves across habitat cells and resumed normal feeding behavior within one or two minutes.

A comparison of diver transect counts for 1989 and 1991 are presented in Figure 3. Figure 3 includes a line of equality identifying the value where both Diver A and Diver B counts are equal. We found significant correlation between divers in both 1989 ($r=0.94$) and 1991 ($r=0.95$). Snorkel counts could not be calibrated with other sample methods, such as seining or electro-fishing, because the river is too large to sample effectively with these methods. Differences in counts between divers are probably real, since fish were free to move in and out of habitat cells as they chose.

Microhabitat Use

Figure 4 shows the relationship between WUA in habitat cells and the average density of juvenile chinook salmon observed per habitat cell in 1989 and 1991. Linear regression analysis of habitat cell WUA versus mean fish density for 1989 ($R^2=0.89$) and 1991 ($R^2=0.72$) describe a relationship between microhabitat quality, as described by depth and velocity use criteria, and numbers of juvenile chinook salmon. Based on these relationships, approximately 0.103 and 0.019 juvenile chinook salmon per square foot of WUA were present in 1989 and 1991, respectively. The density of juvenile chinook salmon per square foot of WUA in 1991 was 82 percent less than in 1989. In high quality microhabitat cells, those cells where WUA and surface area were nearly equal, the density of juvenile chinook salmon in 1989 was 0.501 fish per square foot of WUA, and in 1991 it was 0.215 fish per square foot of WUA, a decrease of 57 percent.

Three transects at the Cemetery study site, a run (C1), riffle (C2), and pool (C9), were sampled in both 1989 and 1991. A comparison between mesohabitat transects sampled in the Cemetery study site in 1989 and 1991 found that the average number of juvenile chinook salmon was 53 percent less in 1991 than in 1989 (Figure 5). In both years the run mesohabitat (C1) supported the greatest number of fish per square foot of WUA. Approximately 0.96 fish per square foot of WUA in 1989 and 0.52 fish per square foot of WUA in 1991.



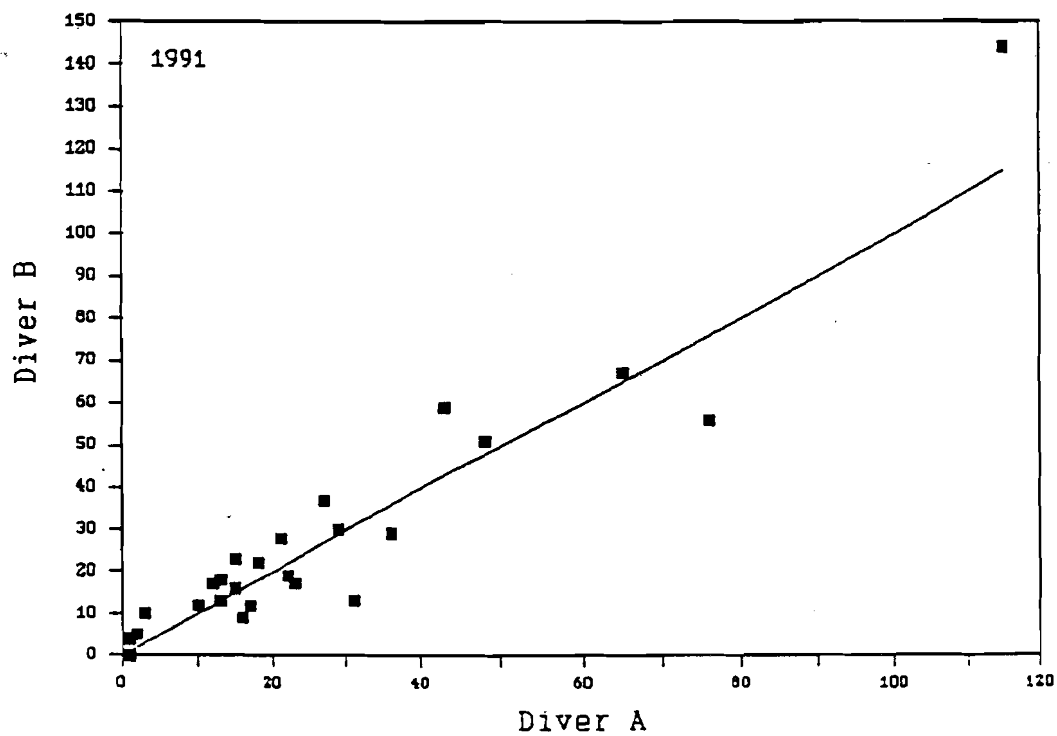


Figure 3. Comparison between snorkel diver mesohabitat transect counts of juvenile chinook salmon in the Trinity River during 1989 and 1991.

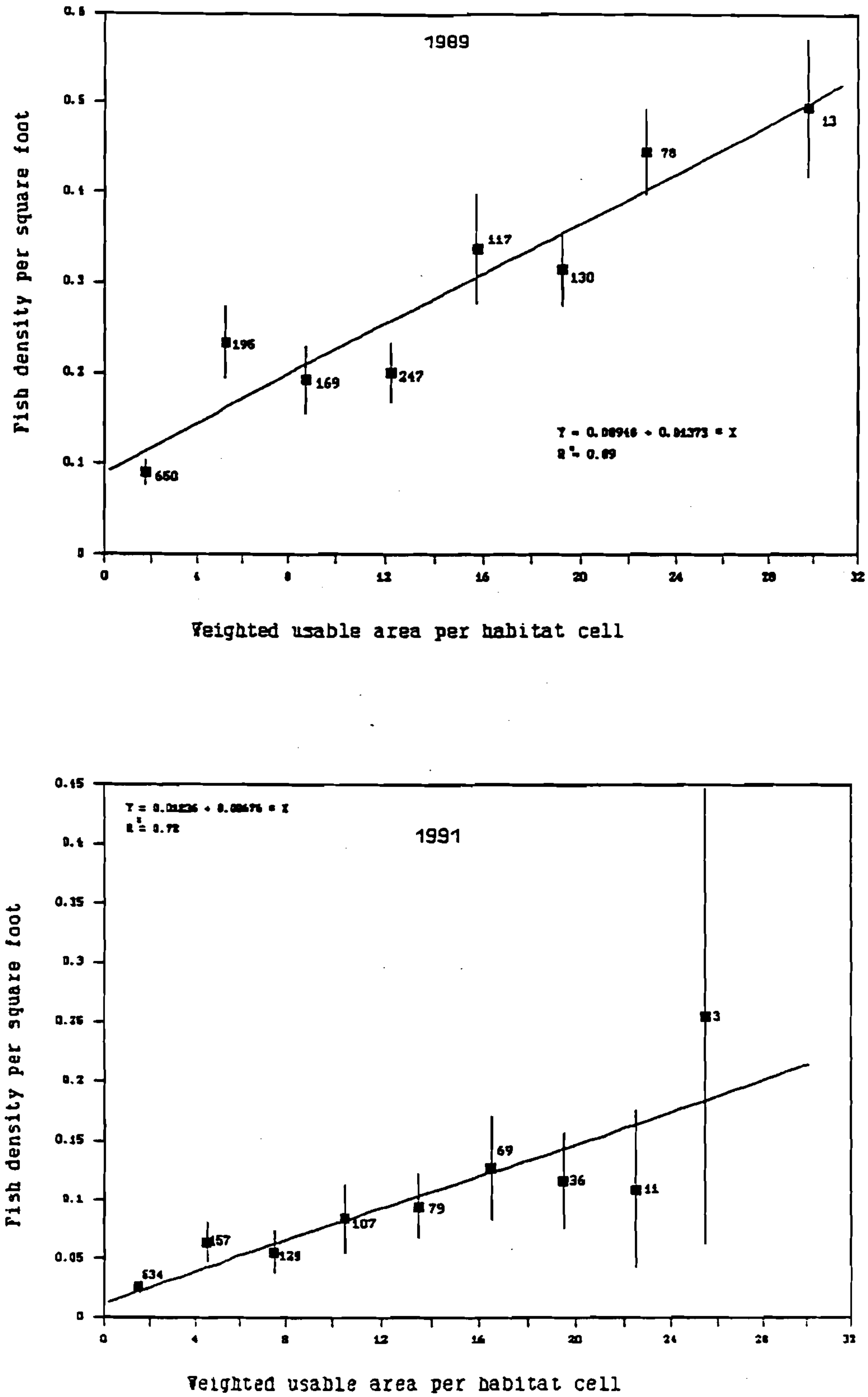


Figure 4. Mean density of juvenile chinook salmon versus weighted usable area in microhabitat cells in the upper Trinity River in 1989 and 1991.

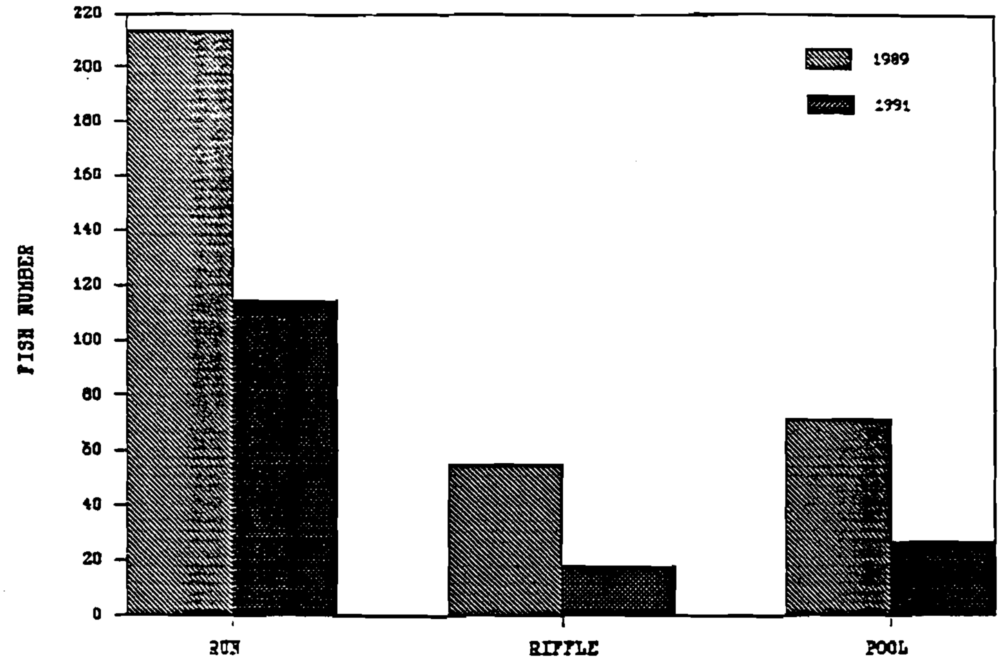


Figure 5. Average number of juvenile chinook salmon observed across three mesohabitat transects in the Cemetery study site in 1989 and 1991.

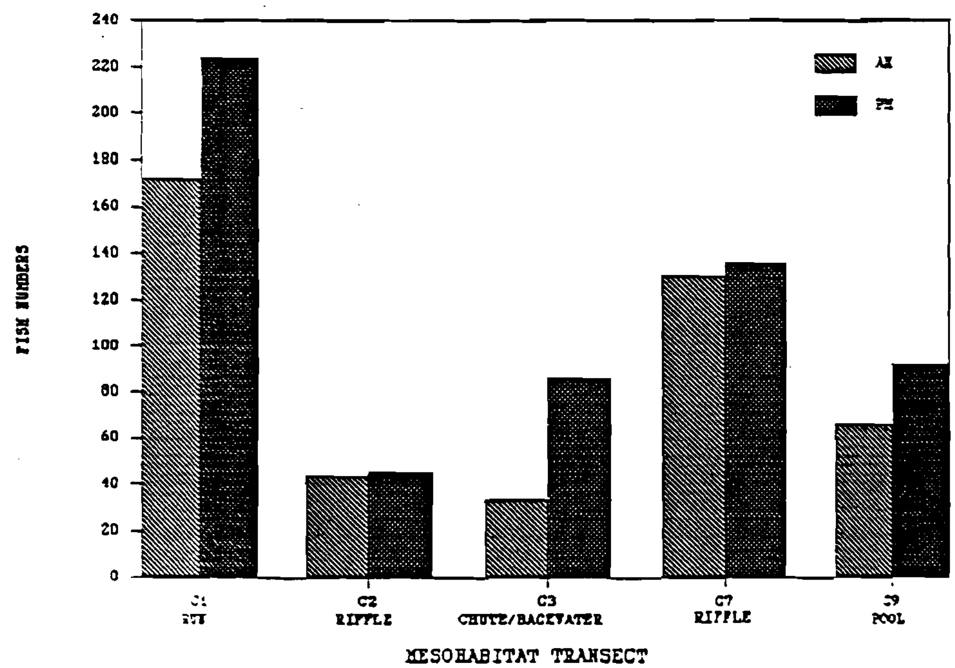


Figure 6. Average number of juvenile chinook salmon counted across five mesohabitat transects in the morning and afternoon of April 12, 1989.

The California Department of Fish and Game (Zuspan, pers. comm.) estimates that 83,945 spring and fall run chinook salmon spawned naturally in the Trinity River above Willow Creek in 1988, while only 10,562 are estimated to have spawned in the same area in 1990. The reduced number of spawners in 1990 resulted in fewer juvenile chinook salmon in 1991 versus 1989.

Daily Habitat Shifts

On 12 April 1989, we conducted transect counts in the morning starting at 9:30 AM and then repeated transect counts starting at 1:30 PM. Our results showed a shift in the distribution and density of juvenile chinook salmon between the two sampling efforts in run, backwater, and pool mesohabitats (Figure 6). In the afternoon juvenile chinook salmon distribution and densities had increased toward thalweg areas of faster and deeper water (Figure 7). It appears that daily habitat shifts occur gradually throughout the daylight hours and complete habitat saturation probably does not happen until late in the afternoon. Future studies to develop habitat suitability criteria for rearing salmon should direct effort toward afternoon hours to collect data under full habitat saturation conditions.

Mesohabitat Use

A summary of fish use, WUA, and numbers of fish per square foot of WUA for each transect sampled in 1991 is presented in Figure 8. The greatest numbers of juvenile chinook salmon were found in Cemetery 1 (115 fish), Bucktail 2 (66 fish), Poker Bar 3 (40.75 fish), and Steel Bridge 5 (33.25 fish), run mesohabitat types. The lowest number of juvenile chinook salmon observed was 1.5 fish in the run mesohabitat at Poker Bar 1. The remaining transects contained an average of fewer than 27 fish each. We found that the number fish per square foot of WUA across the various transects averaged 0.225 (±0.087 95% Confidence Intervals) and ranged from 0.015 to 0.562 fish per square foot of WUA. Since WUA is based on microhabitat suitability, in theory, the number of fish per unit of WUA should be equal for all mesohabitat types. The results presented here indicate that there may be variation in the number of fish per WUA for different microhabitat cells and mesohabitat types.

Close examination of the distribution of microhabitats within each mesohabitat transect may provide a better understanding of the relationships between microhabitat, mesohabitat, and fish use. This may help explain the variation in fish numbers per WUA observed in this study. Figures 9 through 12 show a graphic representation of total depths, water velocities, WUA, and fish numbers across each transect sampled in 1991. All figures are drawn to scale. Total depths are presented in feet and mean column water velocity in feet per second. Weighted usable area is shown as the total square feet of WUA per cell and fish numbers are presented as the average number of juvenile chinook salmon observed per cell.

Cemetery Study Site

In the Cemetery study site four transects were selected in three mesohabitat types, one in a run, two in riffle/pocket-waters, and one in a pool. Transect profiles, WUA, and number of fish observed for the Cemetery study site are shown in Figure 9. Transect C1 is located across a run mesohabitat. Water velocity and depth gradually increase toward the thalweg where the total depth peaks at 3.3 feet with a mean column velocity of 2.4 feet per second. Boulders and a small log provide cover along the left bank. A small log and some sparse aquatic vegetation provide minimal cover along the right bank. Cobble substrate embedded between 30 and 90 percent in sand are present across most of the transect. Fish numbers corresponded well with measured WUA across the transect with one exception. The cell containing the greatest amount of WUA was located along the right side of the transect; the number of fish observed in that habitat cell was lower than in adjacent habitat cells located in slightly faster water toward the

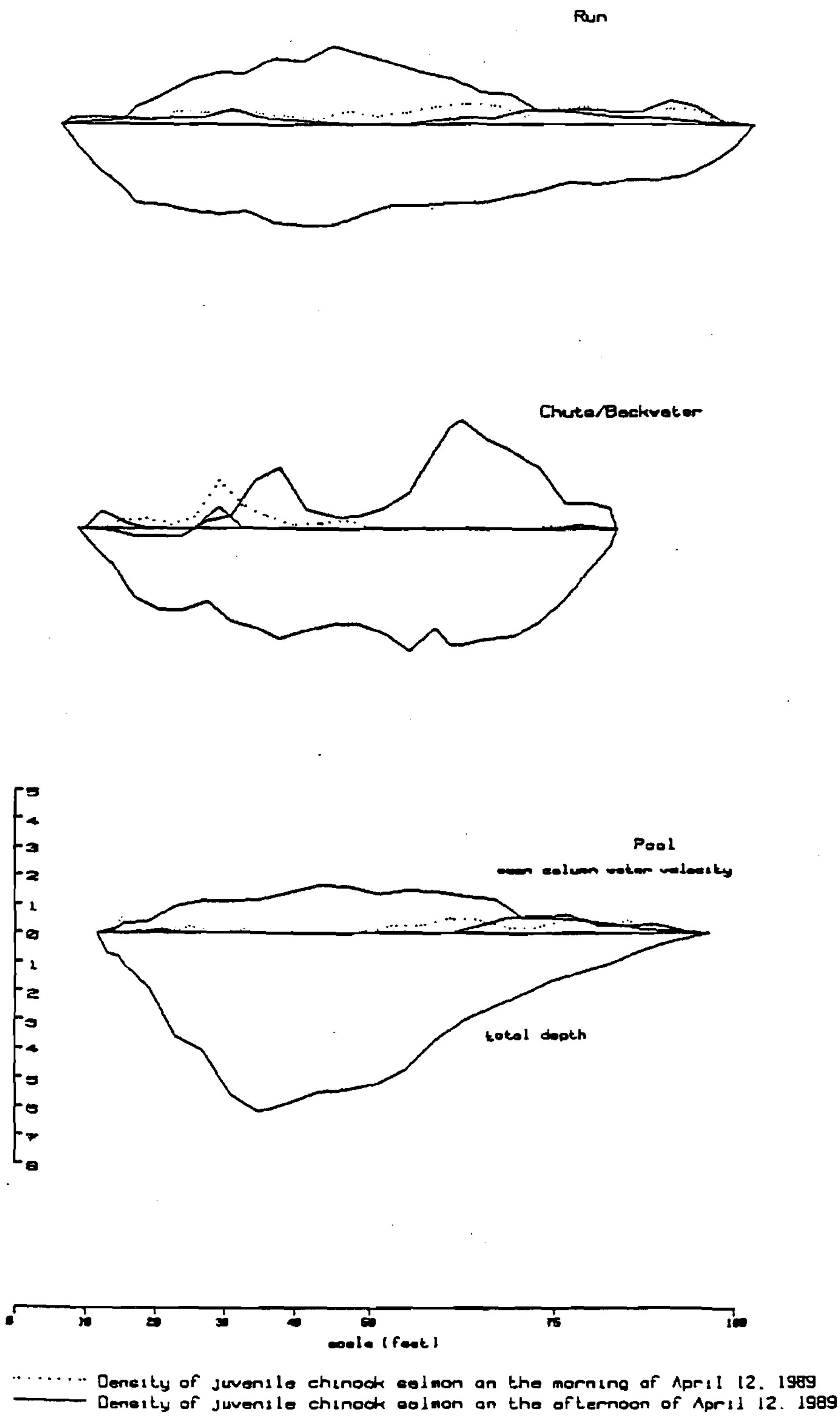


Figure 7. Comparison of juvenile chinook salmon densities (fish/feet^2) along three mesohabitat transects in the Cemetery study site in morning and afternoon of April 12, 1989.

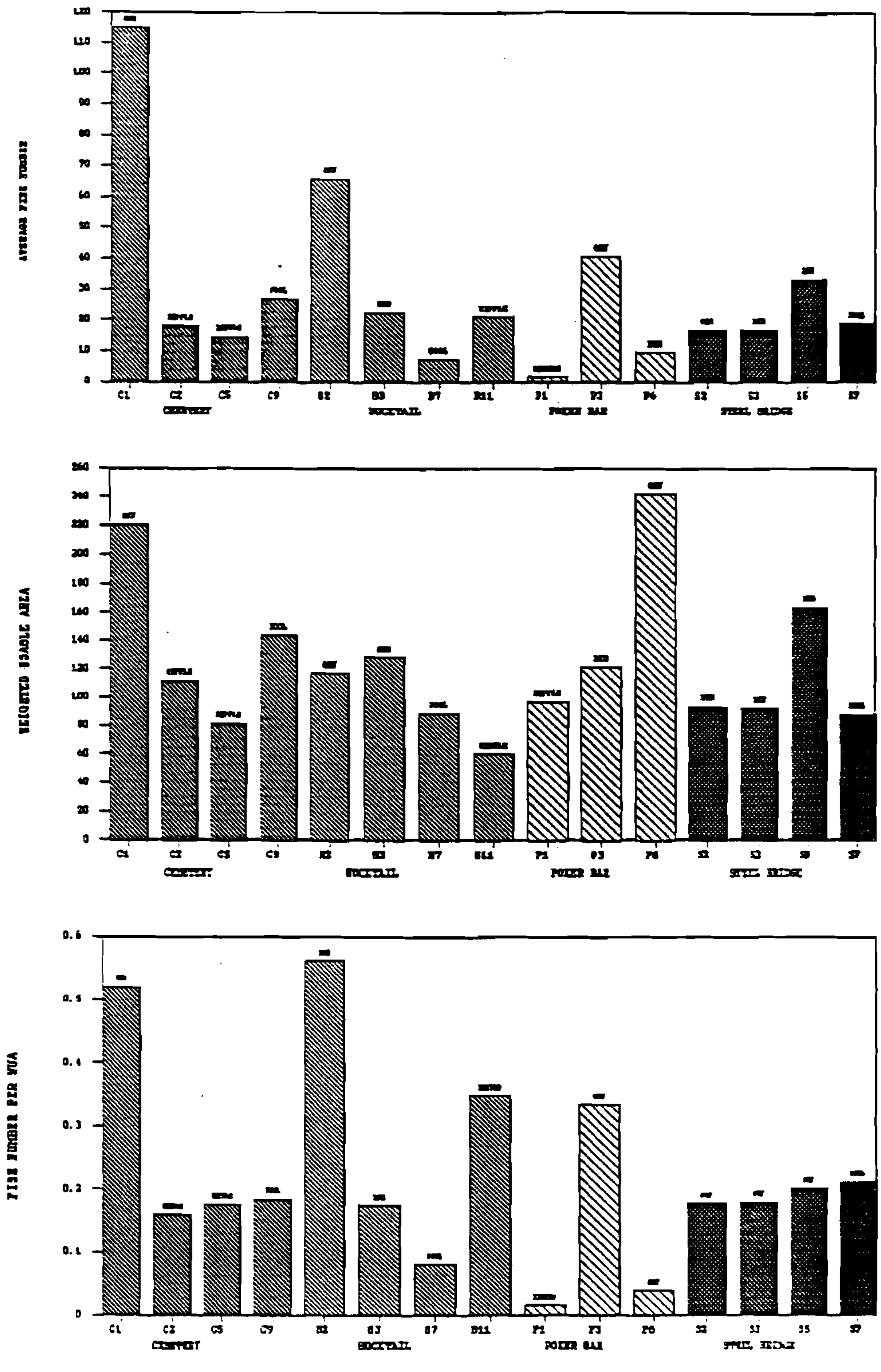


Figure 8. Mean number of juvenile chinook salmon, weighted usable area, and average number of juvenile chinook salmon per weighted usable area for each mesohabitat transect sampled in the Trinity River in 1991.

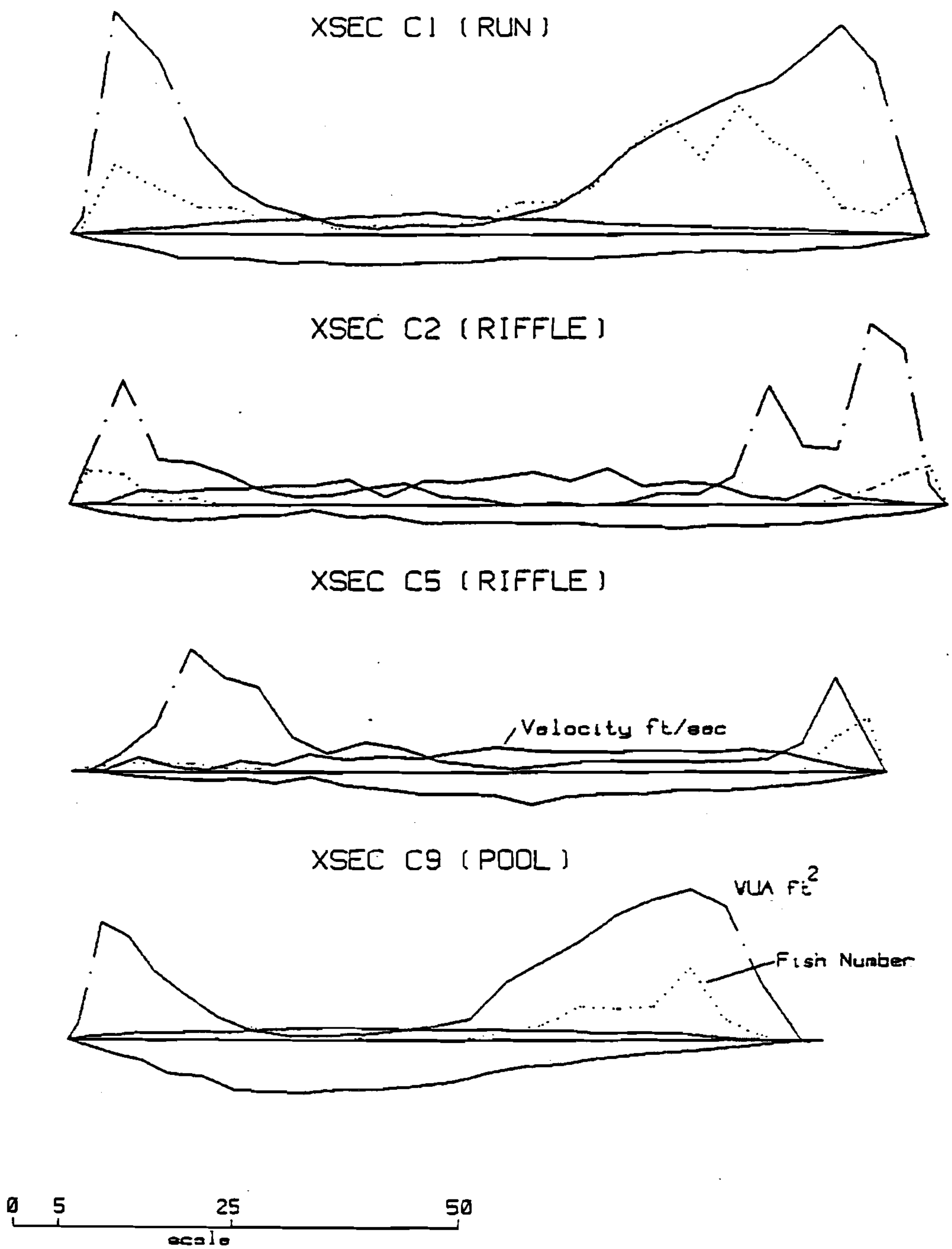


Figure 9. Transect profiles for the Cemetery study site showing total depths, mean column water velocities, water surface elevations, WUA, and the average number of juvenile chinook salmon observed in 1991.

thalweg. The habitat cells where the greatest number of fish were observed contained cobble substrate 80 percent embedded in sand. The closest cover was over 13 feet away along the right edge. Schools of juvenile chinook salmon were distributed throughout the water column in the cells along each bank. As water velocities increased with increased distance from the banks, juvenile chinook salmon moved closer to the river bottom, using cobble substrate as velocity shelters. When mean column water velocities began to exceed 1.0 feet per second, the numbers of juvenile chinook salmon that were able to use those habitat cells dropped dramatically as the bottom velocities became too swift. Large juvenile chinook salmon (±100 mm) were able to use those habitat cells where mean column velocities exceeded 1.0 feet per second.

Both transects C2 and C5 are located across riffle-pocket water mesohabitat types. Mean column water velocities range between 0.0 and 4.0 feet per second. However, instantaneous water velocities undoubtedly exceed 5.0 feet per second in many habitat cells. Across transect C2 only four habitat cells contained more than 10 square feet of WUA. Juvenile chinook salmon were never observed in one of these cells located along the right side of the transect. The habitat cells located on each side of this cell contained water velocities in excess of 2.0 feet per second. These high water velocities created a barrier that prevented movement of juvenile chinook salmon from slow edge water habitats into this suitable habitat cell. In diverse habitats, high water velocities or shear velocity zones may have a negative effect on WUA-fish density relationships by isolating suitable habitat areas.

Transect C9 is located across the lower end of a bedrock-formed pool. Mean column water velocities ranged from 0.0 to 1.5 feet per second and total depth peaked at 5.9 feet. The left edge of the transect is formed by bedrock outcroppings. Cobble and gravel substrate, embedded between 40 and 90 percent in sand, are present throughout the thalweg and right side of the transect. Across the entire transect, juvenile chinook salmon were closely associated with the river bottom. Numbers of juvenile salmon and WUA show a good relationship along the right side of the transect. Fish numbers decreased when mean column water velocities began to exceed 1.0 feet per second, similar to our finding across transect C1. In 1991, no fish were ever observed in the cells that contain suitable microhabitat along the left bank. However, in 1989 when population levels were much higher, we did observe regular use of these habitat cells. Upstream from these cells the thalweg deflects off of a bedrock outcropping forming an eddy upstream. The current deflects away from the left bank downstream along the right side of these habitat cells. The physical characteristics upstream and adjacent to the area may prevent many juvenile chinook salmon from coming in contact with these suitable habitat cells. In 1989, when large numbers of juvenile chinook were present in the river, the probability of juvenile chinook salmon seeding these isolated microhabitats was undoubtedly greater, thus accounting for their presence in 1989. Large numbers of juvenile chinook salmon are commonly observed using the eddy upstream on the other side of the high velocity zone that deflects off of the bedrock bank.

Bucktail Study Site

At Bucktail, four transects were sampled, two in a run, one in a pool, and one in a spawning riffle (Figure 10). Transect B2 represents a run mesohabitat. Maximum mean column water velocities were 2.5 feet per second and the maximum depth measured was 3.9 feet. Small woody debris provided an excellent source of cover along both river banks. Some cover is also provided by small boulders and cobbles embedded less than 40 percent in sand. Fish numbers corresponded well with measured WUA across this transect. As was true for the Cemetery study site, the largest number of juvenile chinook salmon observed across the transect were not directly associated with cover. All fish observed along the left half of the transect were close to the river bottom using small velocity shelters located between cobble substrate. Larger juveniles were able to use microhabitats near the thalweg where mean column water velocities

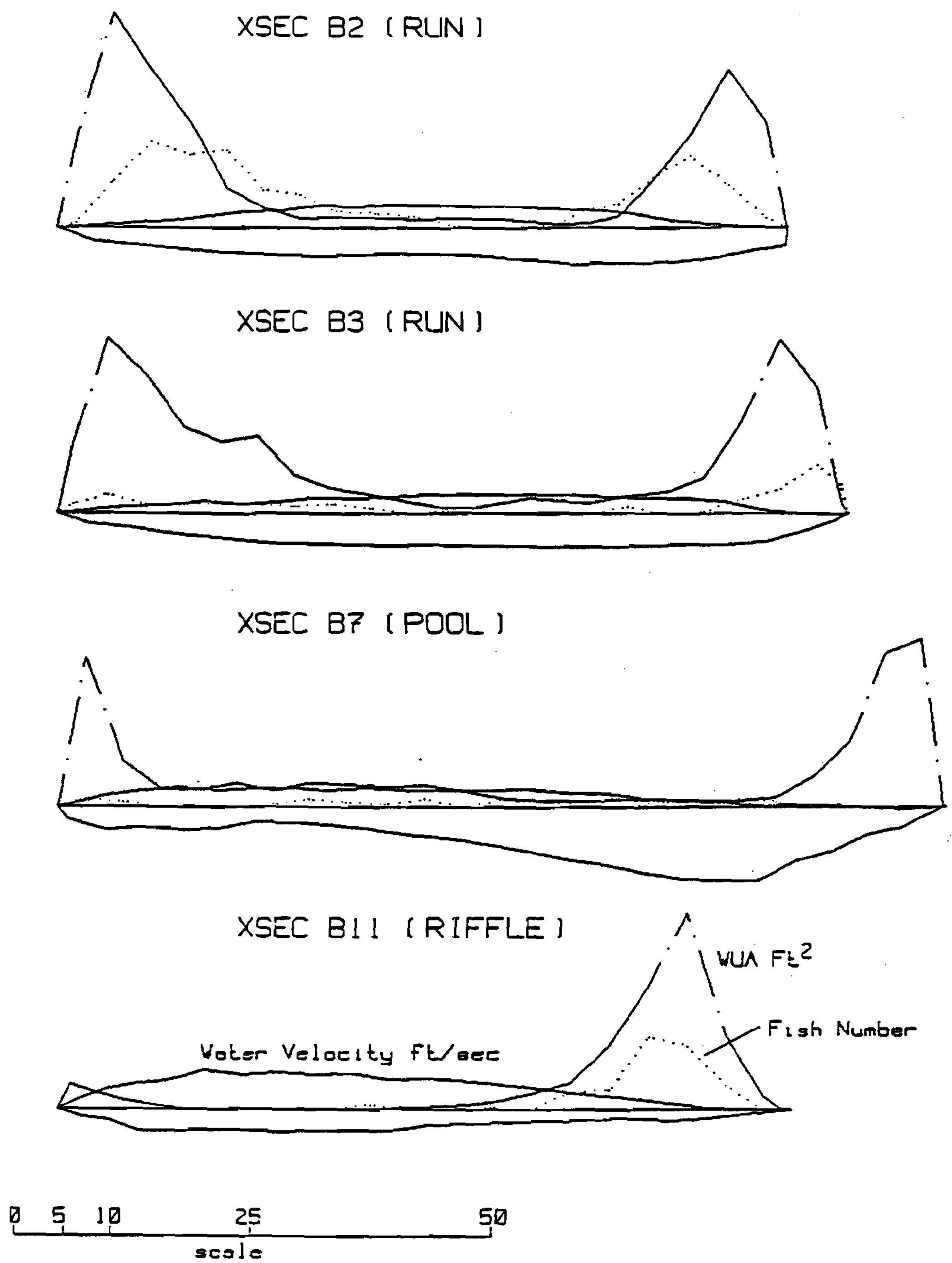


Figure 10. Transect profiles for the Bucktail study site showing total depths, mean column water velocities, water surface elevations, WUA, and the average number of juvenile chinook salmon observed in 1991.

approached 2.5 feet per second. These larger juveniles held in the velocity shelters behind large cobbles. Along the right edge of the transect juvenile chinook salmon distributed throughout the water column adjacent to and in submerged woody cover. The mean column water velocity in these habitat cells was less than 0.4 feet per second.

Transect B3 is located 205 feet downstream from transect B2 in the same run mesohabitat and has similar microhabitat conditions. Transect B3 does not contain woody cover along either edge and water velocities across the transect are slightly slower and the overall average depth greater. Mean column water velocities across the thalweg ranged from 1.6 to 2.0 feet per second. Submerged aquatic vegetation provides some cover along the right bank. Although fish were present in those cells that contain suitable microhabitat, the number of fish observed per cell was far less than the number of fish found using transect B2. One possible explanation for the differences in fish use between these two similar transects might lie in their relative location to other mesohabitat types. Transect B2 is closer to a riffle upstream; whereas transect B3 is located closer to a long, deep, slow pool downstream. Hatchery steelhead were also observed across transect B3 on more occasions than across transect B2. This may have had some impact on juvenile chinook salmon use of the microhabitat along transect B3.

Transect B7 is located in a slow pool just downstream from very turbulent water. The left bank is formed by a cobble-gravel bar that experienced severe agrading in 1986. The bar slopes downward to a total depth of 7.8 feet. Large bedrock ledges and boulders make up the right bank. This transect supported an average of only 7.25 juvenile chinook salmon, the second lowest number of fish per mesohabitat observed. Although only 7 fish used the transect, they were all large juveniles, exceeding 100 mm in length. Two habitat cells located along the right edge of the transect contained approximately 33 square feet of WUA, yet juvenile chinook salmon were never observed in those cells. Mean column water velocities across 22 feet along the right side of the transect never exceeded 0.2 feet per second. Mean column water velocities exceeding 0.5 feet per second were more than 20 feet away from the two habitat cells that contained most of the WUA on the transect.

The fact that these two habitat cells were located in a large area of slow water resulted in a negative effect on overall habitat quality, even though WUA was high. Without the benefit of higher water velocities nearby to deliver food, the actual quality of slow water microhabitats for juvenile chinook salmon was greatly reduced. This transect provides an excellent example of the influence that adjacent physical conditions can have on the use of otherwise suitable microhabitat cells by juvenile chinook salmon. It also provides an example of the possible errors that can occur within PHABSIM by over-estimating WUA for a species lifestage. This is possible because although juvenile chinook salmon prefer slow water within a certain range of depths, they were not found in all microhabitat areas of the river where those water velocities and depths were present.

Transect B11 is located across a salmon and steelhead spawning riffle. Proceeding from left to right across the transect, water velocities and depths increased to over 4.0 feet per second and 2.3 feet deep within the first 12 feet. From this point in the thalweg, water velocities and depths gradually decrease along a gravel bar forming the right bank. In total numbers of fish observed this transect supported an average of 21 juvenile chinook salmon. This transect exhibited the best relationship between WUA and observed fish use. Slow water microhabitat located along the right edge of the transect, near increasing water velocities, created ideal microhabitat for rearing juvenile chinook salmon.

Poker Bar Study Site

Poker Bar is located downstream from the confluence of Grass Valley Creek. As a result, the substrate throughout the Poker Bar site contain excessive amounts of decomposed granitic sand. The increased sediment load has degraded the quality of food-producing areas, over-wintering habitat, and spawning habitat. Our sampling at the Poker Bar study site included one broad riffle, and two run habitat types (Figure 11).

Transect P1 is located across a wide shallow riffle. Chinook salmon spawn along the right edge. Substrate across the transect are composed of cobble and gravel highly embedded in sand. Small quantities of woody cover were present along the left water's edge. An average of only 1.5 juvenile chinook salmon was observed across this transect, the lowest number of fish observed for any transect. With the exception of the edges, mean column velocities across the transect exceeded 1.5 feet per second. Fast water combined with highly embedded substrate resulted in poor habitat. Highly embedded substrate reduced bed roughness and reduced the number of velocity shelters that could otherwise be used by feeding juvenile chinook salmon.

Transect P3 is located across a deep run mesohabitat with cobble substrate, the majority of which are embedded in more than 80 percent sand. Depths ranged from 3.0 to 4.8 feet. Along the left side of the transect, mean column water velocities ranged from 1.2 to 2.2 feet per second. Mean column velocities along the right side of the transect were much slower, ranging from 0.0 to 0.5 feet per second. The greatest amount of WUA (>10 ft^2) was located in four habitat cells with slow to zero water velocities along the right side of the transect. The greatest numbers of juvenile chinook salmon were located along both edges of the river, and in two habitat cells located near the thalweg, where water velocities start to increase. Along the left edge, chinook salmon juveniles were also associated near a shear velocity zone. Along the right water's edge, we observed some juvenile chinook salmon using woody debris cover in still water. The habitat cells containing the greatest amount of WUA contained only a few chinook salmon. The lack of higher velocity areas near these habitat cells reduced their value to juvenile chinook salmon.

Transect P6 is located across a monotypic run mesohabitat. Depths ranged between 1.6 and 2.6 feet and mean column velocities gradually increased from 0.0 feet per second along each edge to 1.4 feet per second in the thalweg. The substrate were composed of sand or gravel completely embedded in sand. Small woody debris and aquatic vegetation provide some excellent cover for juvenile chinook salmon along the left edge of the transect. Compared to the other transects sampled, this transect contained the greatest amount of WUA, yet ranked twelfth out of fifteen transects for the number of fish supported, with an average of 9.5 juvenile chinook salmon. Environmental factors that contribute to the lack of fish use across this transect that were not included in the calculation of WUA include lack of velocity diversity, lack of any bed roughness elements to create velocity shelters, and excessive sedimentation.

Steel Bridge Study Site

At Steel Bridge study site we sampled four transects (Figure 12). Two transects, S2 and S3, are located across run mesohabitats. With the exception of a few bedrock outcropping along the left side of transect S2, large cobbles, embedded between 30 and 60 percent in sand, dominate the thalweg profiles of both transects. Both transects also share similar depth profiles, but mean column velocities across transect S3 were approximately 0.5 feet per second slower than transect S2. Slower water velocities across transect S3 resulted in slightly higher WUA estimates across the thalweg than for transect S2. However, the total amount of WUA provided by each transect was nearly equal. Transect S2 contains 93.9 square feet of WUA and transect

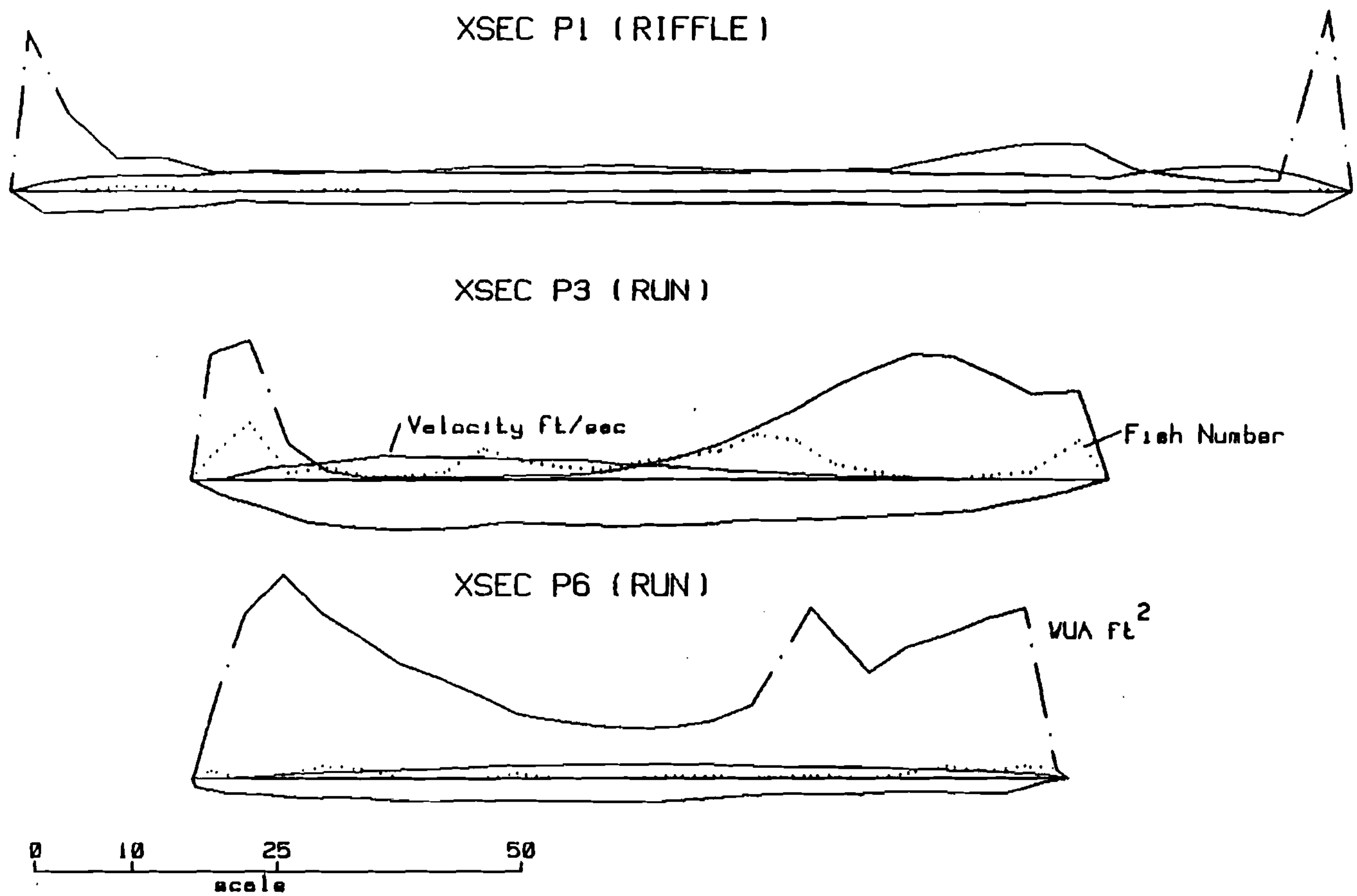


Figure 11. Transect profiles showing total depth, mean column water velocity, water surface, WUA, and number of juvenile chinook salmon observed at the Poker Bar study site, Trinity River, CA, 1991.

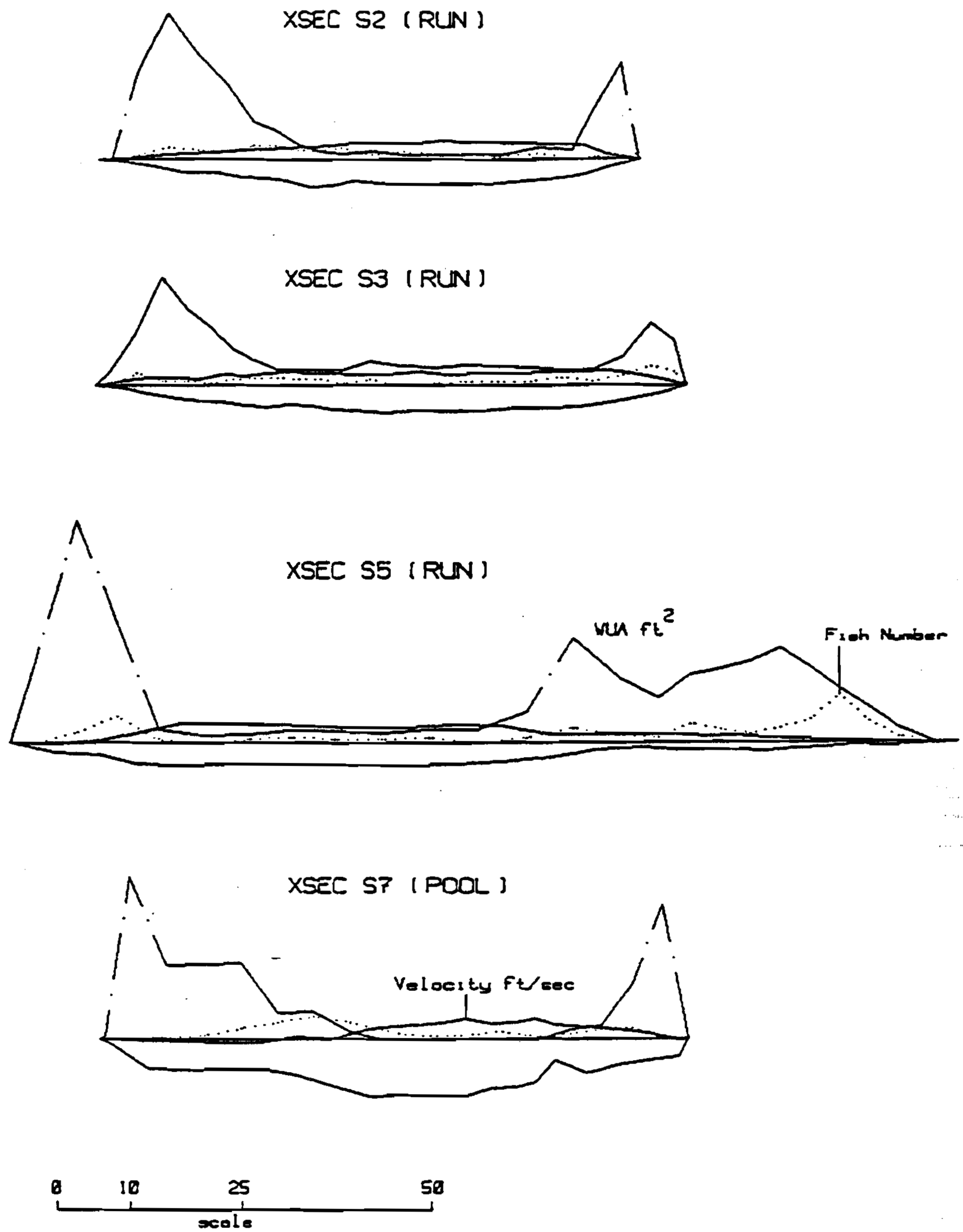


Figure 12. Transect profiles for the Steel Bridge study site showing total depths, mean column water velocities, water surface elevations, WUA, and the average number of juvenile chinook salmon observed in 1991.

S3 contains 92.9 square feet of WUA. An average of 16.75 juvenile chinook salmon were supported by each transect, ranking them tenth in numbers of fish. The proportionate distribution of fish numbers across these two transects did not resemble the distribution of WUA across the transects. In general, however, more juvenile chinook were found in habitat cells that contained the greatest amount of WUA. Larger juveniles (> 100 mm) were distributed in cells containing higher water velocities across the thalweg between large cobble substrate.

Transect S5 is located just downstream of a mid-channel island. A major spawning riffle is located just upstream of the transect in the river channel to the right of the island. A small backwater is located along the left edge below a small bedrock outcropping just upstream. Depths across the thalweg range between 1.5 and 2.9 feet, and mean column water velocities peak at 2.6 feet per second. The right side of the transect is less than 1.0 feet deep with velocities under 0.5 feet per second. Substrate across most of the channel are composed of cobbles and gravel embedded approximately 20 to 40 percent in sand. Cobble substrate across the right side of the transect are embedded up to 90 percent in sand.

Transect S5 ranked third in WUA with 164 ft^2 and ranked fourth in numbers of fish with an average of 33.25 chinook salmon. Observed fish numbers corresponded well with WUA across the transect. Along the left edge of the transect, juvenile chinook salmon were distributed throughout the water column feeding on drift organisms that passed through the shear velocity zone. Small juvenile chinook salmon were distributed across the right side of the transect in shallow water. The larger juveniles (> 100 mm) were distributed across the bottom between large cobbles in faster and deeper water.

Transect S7 is located across a pool. Depths reach up to 7.4 feet and mean column water velocities peak at 2.8 feet per second. A large backwater is present along the left half of the transect. Sand is present along the left side of the transect, cobbles are distributed across the middle the transect, and large boulders are located along the right side. The greatest number of juvenile chinook salmon observed on this transect were dispersed throughout the water column in association with the edge of the shear velocity zone that forms the boundary between the thalweg and eddy. These fish moved in conjunction with the surging lateral movement of the velocity shear zone, feeding on drift organisms throughout the water column.

No juvenile chinook salmon were observed using the cell along the left edge that contained the greatest amount of WUA. This habitat cell provides another example of a situation where the absence of higher velocity microhabitats nearby had a negative impact on the habitat suitability, even though the depths and velocities present within the habitat cell predicted high quality microhabitat.

DISCUSSION

In this investigation we have attempted to describe and validate the relationship between WUA and standing crop of juvenile chinook salmon in the upper Trinity River. In doing so, we have discovered several variables that influence and complicate efforts to quantify this relationship. These factors include microhabitat isolation, effects of velocity shear zones on microhabitat quality, and a lack of habitat diversity. It may be possible to increase the accuracy of habitat predictions for juvenile chinook with the PHABSIM system by using the nose velocity option in conjunction with the HABTAV program. Use of adjacent velocity criteria should improve exaggerated habitat predictions in large areas of slow water and increase habitat quality predictions in areas near shear velocity zones.

Currently, the model seems to underestimate the value of mid-channel areas with cobble substrate where water velocities are greater than 1.0 feet per second. These midchannel microhabitats have been shown to support large numbers of juvenile chinook salmon. In these habitats larger juveniles disperse along the bottom using small velocity shelters among the cobbles. The use of HABTAV should improve habitat predictions in these areas. An alternative solution might include the development of conditional criteria that incorporates substrate roughness elements or embeddedness values when mean column velocities begin to exceed 1.0 feet per second. We could have used a substrate channel index in the calculation of WUA, but this would not have increased the accuracy of the WUA estimates in this study, since our substrate criteria for juvenile chinook salmon show a high suitability for sand and highly embedded substrate. There is little doubt that these substrate suitability values are more the result of a combination of poor habitat conditions in the Trinity River and the hydraulic characteristics present in microhabitats selected by juvenile chinook salmon, than they are a factor of preference by juvenile chinook salmon for sandy substrate. Therefore, if conditional substrate criteria are to be used in the future they will have to be derived from professional judgement and applied only in specific mesohabitat types.

The fact that fish densities in high quality habitat cells differed between sampling years indicates that preferred microhabitats do not fill to capacity before lesser quality microhabitats are used. In both 1989 and 1991 juvenile chinook salmon distributed themselves throughout the full range of suitable microhabitats in similar proportions even though population levels were much lower in 1991. When high quality microhabitat areas are limited, many fish may not be able to locate those areas. Under these conditions seeding of optimum microhabitats may be a function of random search, time, and population levels.

On the Trinity River each IFIM transect represents a specific mesohabitat type. The river was habitat-mapped based on the physical characteristics of each mesohabitat transect. The WUA predictions for each mesohabitat transect were then extrapolated based on this habitat map to get a total estimate of available habitat for the river. Habitat in the upper river is currently described by fifty five mesohabitat types or transects. In this investigation we have described fish per WUA relationships for fifteen of these transects. In 1991 the number of fish per square foot of WUA per mesohabitat transect ranged from 0.015 to 0.562 with an average of 0.225 fish per square foot of WUA. The variation in numbers of fish per square foot of WUA between transects was high with 95 percent confidence intervals of 0.138 and 0.311. Based on the large variation that was observed in numbers of fish per WUA between mesohabitats it appears that each mesohabitat type within the population model will need an independent fish per WUA value. This greatly increases the amount of field work that will be required since each mesohabitat will need to sampled each year to obtain model input data. This may not be necessary if habitat predictions can be improved through the use of HABTAV or some conditional substrate criteria that results in a substantial reduction in the variation of fish per WUA values between mesohabitat types.

Between Lewiston and Douglas City there are approximately 3,250,000 square feet of WUA for juvenile chinook salmon at a river flow of 300 cfs. In this study we found an average of 0.225 fish per square foot of WUA among the mesohabitats that were sampled. Using these numbers, in 1991 approximately 731,250 (± 282,858) juvenile chinook salmon reared in the upper Trinity River. If we assume a one percent survival to escapement, a total of 7,313 naturally produced adults will return to the Trinity River from the 1991 cohort. This is far short of the Trinity River Restoration Programs escapement goal of 68,000 returning natural adult chinook salmon. Unless flows are dramatically increased to mimic historic patterns it seems doubtful that natural populations of chinook salmon will ever recover to their historical levels.

APPENDIX H

DEVELOPMENT OF HABITAT PREFERENCE CRITERIA FOR ANADROMOUS SALMONIDS OF THE TRINITY RIVER

By

Mark Hampton
Trinity River Flow Evaluation Program
U.S. Fish and Wildlife Service
P.O. Box 174
Lewiston, California 96052

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U.S. Fish & Wildlife Service
Division of Ecological Services
2800 Cottage Way, Room E-1803
Sacramento, California 95825

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ABSTRACT

Direct observation techniques using a mask and snorkel were used to collect microhabitat suitability criteria describing depth, velocity, cover, and substrate used by anadromous salmonids of the Trinity River in Northern California. Category II criteria (utilization) are presented for fry, juvenile, and spawning lifestages of chinook and coho salmon and steelhead trout. Available habitat for the upper Trinity River was obtained through the use of the IFG-4 program of the Instream Flow Incremental Methodology (IFIM). Category III criteria (preference) are developed for fry, juvenile, and spawning lifestages of chinook and coho salmon and for juvenile and spawning lifestages of steelhead trout in the upper Trinity River. Preference criteria could not be developed for fry steelhead trout because of a limited sample size.

Utilization and preference criteria descibing water velocity suitabilities for juvenile steelhead trout may not accurately describe microhabitat requirements when focal point velocities, either taken as mean column velocities or as nose velocities, are measured during use data collection. Focal point water velocities fail to measure the presence of shear water velocity zones that are located adjacented to either side of the focal point. It is the presence of these shear zones that provide the target species with optimum feeding stations.

ACKNOWLEDGMENTS

Special appreciation is owed to the entire staff of the Lewiston Field Office of the Trinity River Flow Evaluation Study for their assistance, which made the completion of this study possible. They are fishery biologists Andrew Hamilton, Richard Macedo, Phillip North, William Somer, Randy Brown, and supervisor Mike Aceituno. Further thanks are also extended to biologist Melanie McFarland and laborer Richard Williams of the Sacramento Field Office for their help on various occasions throughout the study.

California Department of Fish and Game biologist Ed Miller provided valuable first hand knowledge of the Trinity River, which assisted in our preproject scoping. The staff at Trinity Hatchery were of help on several occasions and their cooperation and assistance is appreciated.

A very warm thanks goes to Fish and Wildlife Service biologist Jody Hoffman for all his efforts and support in getting this study authorized and underway.

Finally, I would like to express my gratitude to Gwyn Hampton who spent many hours entering field data into computer files.

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INTRODUCTION

The Trinity River Basin drains approximately 2,965 square miles of Trinity and Humboldt counties in Northwestern California. As the largest tributary to the Klamath River, the Trinity has historically been recognized as a major producer of chinook salmon (Oncorhynchus tschawytscha), coho salmon (O. kisutch) and steelhead trout (Salmo gairdneri). Chinook and coho salmon produced within the Trinity River contribute substantially to the offshore commercial troll industry and to both the offshore and inriver sport fishery. The Hoopa Valley Indian Reservation borders the lower twelve miles of the Trinity River, where the Hupa Indians maintain a net fishery to fulfill their subsistence and ceremonial needs. The Trinity Basin also supports other important resource based industries, of which timber, mineral, and water resources hold vast economic importance to the region.

The Trinity River Division of California's Central Valley Project, operated by the U.S. Bureau of Reclamation, is the only major water development project in the Trinity Basin. The project's primary purpose is to divert water from the Trinity Basin to California's Central Valley. As a secondary benefit, hydroelectric power plants produce electricity at various locations throughout the water diversion system. Of the natural spawning area available to chinook salmon in the Trinity River above the North Fork Trinity River confluence approximately 50% was found above the sites of Trinity and Lewiston Dams (Moffet and Smith 1950). The California Department of Fish and Game estimated that 64% of the total habitat once available to steelhead trout had also been lost in the Trinity River as a result of dam construction in 1957 (Hubbel 1973). As partial mitigation for these upstream losses the Trinity River Fish Hatchery was constructed at the base of Lewiston Dam. In addition to hatchery operations, minimum downstream flow releases were provided to maintain fishery resources.

Coincident with the construction and operation of the Trinity River Division, logging accelerated within the Trinity Basin. High watershed erosion rates combined with reduced river flows below Lewiston Dam resulted in extensive sedimentation of fish habitat in the Trinity River below Lewiston. Reduced river flow also allowed riparian vegetation to encroach along the river banks forming a confined U shaped channel eliminating wide gravel bars, resulting in a loss of both valuable spawning and juvenile rearing habitat. Maintenance of minimum river flows and the operation of Trinity Fish Hatchery were not sufficient mitigation to sustain fishery populations. In some stocks, notably steelhead, escapement declines have exceeded 90% in some years.

In response to fishery declines and to aid in the rehabilitation of the anadromous fishery the U.S. Fish &

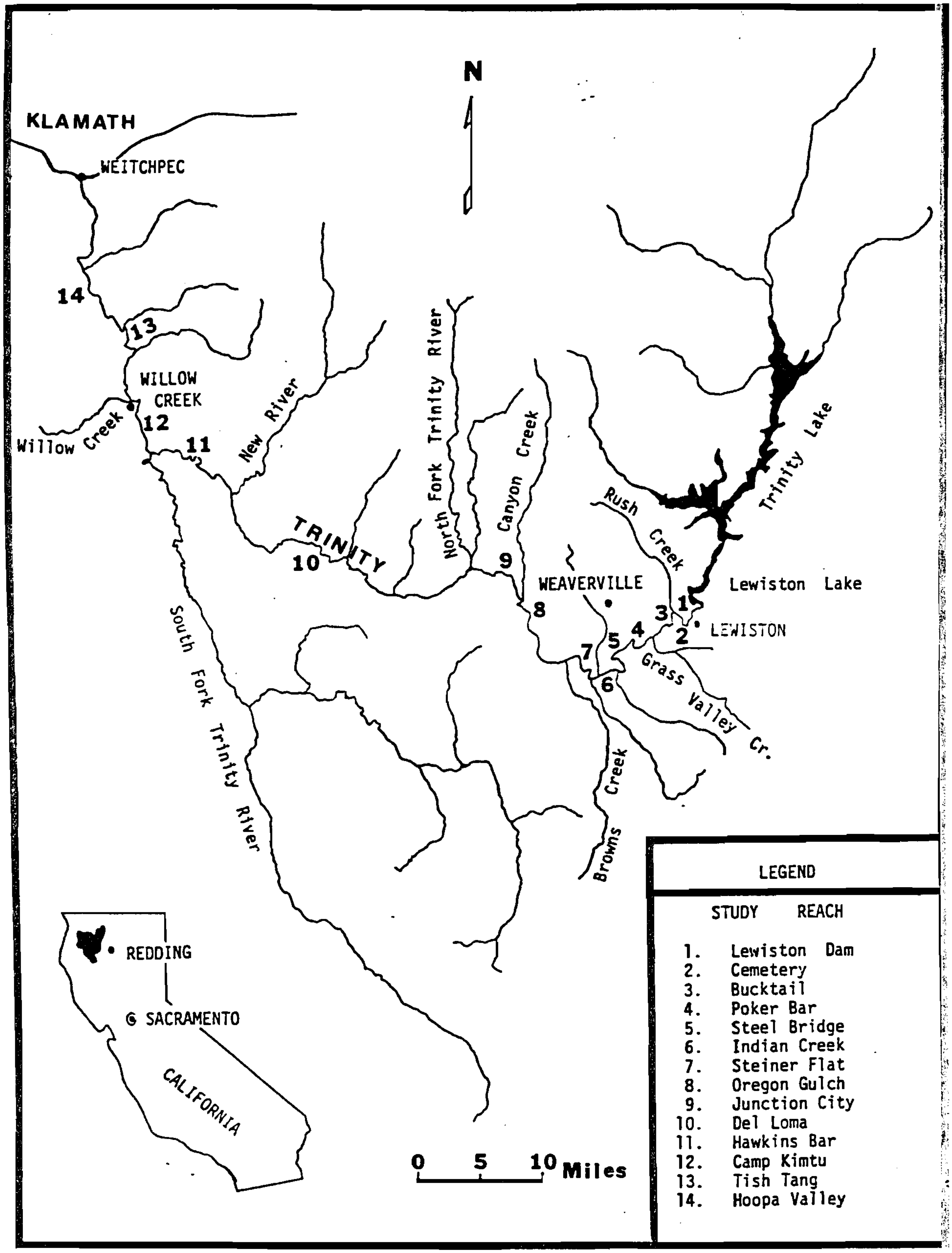


Figure 1. Trinity River Basin with habitat preference study site locations depicted.

Wildlife Service and the U.S. Bureau of Reclamation reached an agreement in December of 1980 to increase flow releases to the Trinity River below Lewiston Dam. The agreement was approved by the Secretary of the Interior in January of 1981. In addition to increasing flow releases for fishery purposes, the agreement provided for a 12-year study to monitor the fishery response to these increased flows. The resulting Trinity River Flow Evaluation was developed and a field office was established in Lewiston.

The study uses the Instream Flow Incremental Methodology (IFIM) created by the Instream Flow and Aquatic Systems Group of the U.S. Fish & Wildlife Service (Bovee 1982) to monitor habitat changes. A key element to the IFIM is the development of habitat suitability criteria describing either habitat use or preference for the target species of concern. Habitat suitability criteria may be separated into three categories dependent on the origin from which the criteria is developed. Category I criteria are based on professional judgment or on information gathered from extensive literature review. Category II criteria (utilization) are developed from observations on the target species taken in the field. These criteria may not represent actual microhabitat preference since they are dependant on the environmental conditions that were available to the target species at the time in which the observations were made. Category III criteria (preference) attempt to eliminate the habitat bias present in use criteria by adjusting them for available habitat. The resulting preference criteria tend to be much less site specific and theoretically may be transferred to other habitats outside the original area of study.

This report deals specifically with the development of use and preference criteria for fry, juvenile, and spawning lifestages of chinook and coho salmon and steelhead trout of the mainstem Trinity River.

STUDY SITE

Fourteen study sites were selected within three major study reaches between Lewiston Dam and Weitchpec (Figure 1). The upper reach, from Lewiston Dam downstream to the North Fork Trinity River confluence, is the most important reach for salmon and trout production. This section has been affected most by reduced river flows below Lewiston Dam. Riparian vegetation has encroached along both river banks throughout this reach steepening banks and reducing habitat area for salmonids. The substrate is composed of granitic sand, gravel, and cobble, with small areas of bedrock. Many tributary streams join the river in this reach, some of which provide important habitat for spawning and rearing steelhead trout. Nine study sites have been selected to represent this section.

The middle reach of the river flows from the North Fork Trinity River confluence downstream to the South Fork Trinity River confluence at Salyer. Two study sites, one at Del Loma and one at Hawkins Bar, were selected to represent this reach. The riparian vegetation common in the upper reach disappears almost immediately below the North Fork Trinity River confluence. Seasonal variations in stream flow from the North Fork Trinity River influence the mainstem to a large enough degree to keep the riparian vegetation in check. This section generally follows a bedrock formed channel and contains several deep pools interspersed by long runs and short riffles or chutes. A steep white-water gorge is located between Cedar Flat and Gray Falls. The New River, a fairly large uncontrolled tributary, joins the Trinity in this section. The gorge area was not sampled during the study because of logistics and safety considerations.

The lower river reach extends from the South Fork Trinity River confluence downstream to the Klamath River at Weitchpec and is represented by three additional study sites. This lower reach is characterized by two major habitat types, valleys and canyons. At Willow Creek and Hoopa the river meanders through two valleys where large gravel and cobble bars are present. The remainder of the lower reach typically flows through steep sided canyons and is characterized by deep bedrock pools and glides alternating with short white-water riffles and chutes.

METHODS

Habitat use data was collected for all lifestages of chinook and coho salmon, and steelhead trout. Sampling methods included direct observation with mask and snorkel, from the bank, or from a raft during float trips.

Habitat Utilization

Direct observation made with a mask and snorkel required two persons, one person as the snorkel observer watching fish and one support person to record data, operate the flow meter, and control the raft. Sampling was conducted in a downstream direction at each study site. Sampling in an upstream direction proved to be impossible because of the size of the river and the presence of high water velocities. The observer would work in a zig-zag pattern across the river channel from bank to bank. At each bank sampling in an upstream direction for short distances was done where water velocities permitted. This sampling technique allowed nearly complete coverage of each study site. When fish were spotted, the observer determined the species, lifestage, behavior, and focal point. The support person was then signaled to approach and the observation was completed. When fish were spotted where water was either to deep or swift to stand, the observer would float motionless past the target fish until downstream and out of sight. The observer would then carefully approach the fish from the rear or side and determine whether the fish had been startled. If the observer believed that the fish was not startled, an observation was then made with the assistance of the raft or rope.

When schools of juvenile salmon were encountered, the number of fish in the school was determined and the observation was made at the focal point of the school. When one school of fish was found to occupy more than one microhabitat, additional observations were made in order to accurately represent those microhabitats used.

Habitat measurements for spawning salmon and trout were taken 0.5 feet upstream of the redd in an attempt to simulate prespawning hydraulic and substrate conditions. Fish nose velocities were taken at 0.4 feet from the bottom for all spawning observations (Smith 1973). It was not considered a prerequisite that data only be taken on active redd sites. Data were taken on newly completed redds, unless there was doubt as to which species had constructed the redd in question, in that case, data were not collected. When more than one species was known to be spawning at the same time, data collection was limited to those active redd locations where positive species identification was possible.

Direct observation from a raft proved to be an effective method for data collection of spawning salmonids. The majority of redds were visible from above the water surface since most of the spawning was done in water less than three feet deep. Snorkel observations were still conducted on a periodic basis to verify spawning use in areas that were not easily seen from the raft, such as in deep or turbulent water.

Fourteen parameters were recorded for each microhabitat use observation. The species and lifestage were determined. Fish less than or equal to 50 mm in forklength were considered fry. Fish greater than 50 mm and less than or equal to 200 mm were considered juveniles, and fish greater than 200 mm were considered adults. An estimate of forklength was obtained with the aid of an underwater slate which had a centimeter scale marked on it. Fish behavior was categorized as either holding, roving, feeding or spawning. The total depth and depth of fish were both measured as the distance above the bottom in feet. The depth of fish was measured as the distance from the bottom to the focal point of an individual fish or school of fish. Two water velocities were taken at each observation, a mean column water velocity and a fish nose water velocity. Mean column water velocity was measured at 0.6 tenths from the water surface for water less than 2.5 feet deep; and the average of the velocities measured at 0.2 and 0.8 tenths from the surface for water greater than or equal to 2.5 feet deep. Water velocities were measured with either a Marsh-McBirney model 201 flow meter or a Price "AA" current meter. Depths were measured with a top setting wading rod.

Seven separate cover types were selected to describe cover use (Table 1). A three digit code descriptor was used to describe the cover types present as well as provide a cover quality estimate. The first digit in the code describes the dominant cover type present while the second digit describes the subdominant type, if present. The third code value, which follows a decimal, describes the quality of the cover types present as either poor, moderate, good, or excellent.

Table 1: Cover code descriptions used to develop habitat suitability criteria for the Trinity River Flow Evaluation, Trinity Co., California, 1985-1987.

Code	Cover Type	Description
0	No cover	gravel less than 75mm or any larger material which is embedded to the extent that no cover is available.
1	Cobble	75 - 300mm in size and clear of fines.
2	Boulders	300mm and larger.
3	Small woody debris	brush and limbs less than 9 inches in diameter.
4	Large woody debris	logs and rootwads greater than 9 inches in diameter.
5	Undercut bank	undercut at least 0.5 feet.
6	Overhanging vegetation	within 1.5 feet of the water surface
7	Aquatic vegetation	

recorded as DS.Q where D = Dominant cover type
S = Subdominant cover type
Q = Quality of cover

The substrate compositions present beneath observed fish were described using the Brusven index (Brusven 1977). The Brusven index is composed of a three digit descriptor of dominant substrate, subdominant substrate and percent embedded in fines (DS.%E). The substrate size categories selected for this study are listed in Table 2.

Table 2. Substrate classifications used for habitat utilization criteria development, Trinity River Flow Evaluation, Trinity Co., California, 1985-1987.

Code	Substrate type	Size Range (mm)
0	Fines	< 4mm
1	Small Gravel	4 - 25mm
2	Medium Gravel	25 - 50mm
3	Large Gravel	50 - 75mm
4	Small Cobble	75 -150mm
5	Medium Cobble	150 -225mm
6	Large Cobble	225 -300mm
7	Small Boulder	300 -600mm
8	Large Boulder	> 600mm
9	Bedrock	

Recorded as DS.E, Where D = Dominant particle size
S = Subdominant particle size
E = Percent embedded in fines

Stream characteristics present at each observation were categorized into nine habitat types: pool, run, riffle, side channel, beaver pond, backwater, waters edge, pocket, and bar. Surface turbulence was noted as either present or absent for each observation. The percentage of sky blocked by riparian canopy was estimated for each observation. Additional data recorded for each sampling day included water visibility (estimated in feet), stream discharge, study site, water temperature, weather conditions, observers present, and the date and time of sampling.

Habitat Availability

Available habitat information was obtained through the IFG-4 program component of the IFIM (Milhous et al. 1984). For each discharge and study site sampled the IFG-4 program of the IFIM was run. The results of each run were then used to estimate habitat availability for total water depth, mean water column velocity, cover, and substrate. The total area represented by each transect within the study site was calculated by multiplying the transect weighting factors, both upstream and downstream, by the distance between transects to obtain a total length. The length was then multiplied by the transect width to obtain the area represented by each transect. This transect area was then divided by the total study site area, yielding the proportion of habitat represented by each transect within the study site. Since the transect cells which make up each transect are not always of equal surface area, habitat availability data could not be obtained directly from each cell without some bias. Rather than calculating another proportional value for each cell within the transect, as was done for each transect within the study site, random samples were taken. For each discharge sampled, the wetted width of each transect was normalized to values between 0 and 100. A random number generator was then used to pick points along the wetted width of each transect. The transect cell located at each randomly selected point was then used to obtain the necessary habitat information. The number of random distances to select for each transect was determined by multiplying the proportional area represented by that transect by 250. This procedure provided 250 habitat availability measurements per study site at each discharge sampled (Table 3).

Use of habitat availability estimates generated from IFG-4 program output allowed greater effort to be focused on habitat use data collection in the last year of the study. Effort also shifted to the upper Trinity River, above the North Fork Trinity River confluence, because accurate discharge estimates were not obtained during lower river sampling in the previous year. Without these discharge estimates modeling of lower river habitat availability was impossible. Fortunately this did not affect any significant sampling effort for 1985 since lower river habitats were rarely sampled because of unfavorable conditions such as high water and low water visibility. Use observations that were collected in the lower Trinity River were not included in preference criteria development.

Aceituno and Hampton (1987) compared habitat availability generated from standard random sampling methods with habitat availability generated from the IFG-4 program. They found that for most study sites the two differing methodologies provided similar estimates of habitat availability.

TABLE 3. Method of selecting available habitat measurements from an IFG-4 model output to obtain an estimate of habitat availability on the Trinity River, CA. 1987

XSEC	WEIGHT FAC. UP	DOWN	CELL LEN.	WEIGHTED LENGTH UP	DOWN	TOTAL	XSEC WIDTH	XSEC AREA	% AREA	* 250
1	0.0	0.5	440	0	220	220	91	20020	0.0850	21
2	0.5	0.5	220	220	110	330	77	25410	0.1079	27
3	0.5	0.5	524	110	262	372	87	32364	0.1375	34
4	0.5	0.5	135	262	67.5	329.5	112	36904	0.1568	39
5	0.5	0.5	164	67.5	82	149.5	63	9418	0.0400	10
6	0.5	0.5	194	82	97	179	97	17363	0.0737	18
7	0.5	0.5	349	97	174.5	271.5	85	23077	0.0980	25
8	0.5	0.3	110	174.5	33	207.5	101	20957	0.0890	22
9	0.7	0.5	151	77	75.5	152.5	93	14182	0.0602	15
10	0.5	0.5	375	75.5	187.5	263	82	21566	0.0916	23
11	0.5	0	0	187.5	0	187.5	75	14062	0.0597	15

Data Analysis

Initial data frequencies of habitat use by each species and lifestage were constructed following the guidelines presented by Bovee and Cochnauer (1977). Frequency distributions derived from continuous data seldom result in smooth curves (Figure 2). One method of alleviating inconsistencies is to increase the interval width. To what extent the intervals should be increased, however, is often unclear. Larger intervals result in smoother histograms, but as a result some accuracy may be lost from the original distribution (Bovee 1986). For construction of depth and velocity utilization curves the interval size used for each frequency distribution was calculated using Sturges Rule as cited by Cheslak and Garcia (1987). Sturges Rule provides an estimate of optimum interval size based on data provided as follows:

$$I = \frac{R}{1 + 3.908 \times \text{Log } N}$$

where: I = Optimum interval size

R = Range of observed values

N = Number of observations taken

For example, if data for total depth were collected at an accuracy level of tenths of feet and 100 fish were observed using depths ranging from 0.5 to 2.5 feet, then R would equal 2.0 feet and N would equal 100. The equation would then yield 0.2 feet as the optimum interval or bin width.

Cheslak (pers. comm.) has since informed me that the minor modifications that were presented in a symposium by him to the Sturges formula may violate the theoritical assumptions of the equation. Therefore, future use of the Sturges equation to determine interval sizes should utilize 3.322 in the denominator rather than 3.908 as is presented here. Time constraints did not allow me to verify whether this change would have appreciable effects on the results that are presented here. However, I do not feel that any noticeable changes in the use of the actual Sturges equation would be evident in the final preference criteria because of the application of the running mean curve smoothing techniques explained as follows.

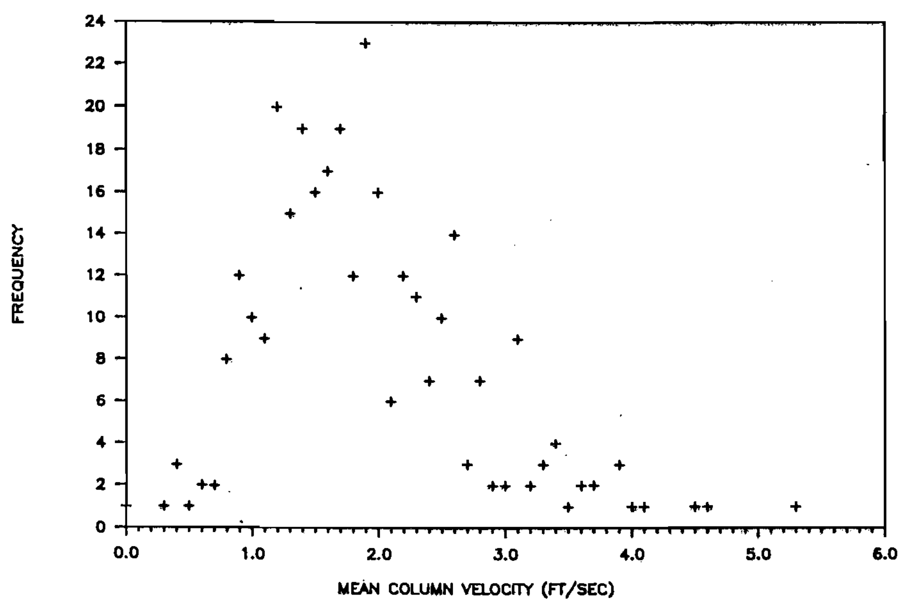


Figure 2. Observed frequency distribution of mean column velocities selected by spawning chinook salmon in the Trinity River, California, 1985-1987.

Once the interval widths were determined, a frequency bar histogram was constructed. The midpoints of each interval were then connected by a straight line. The resulting curve was then subjected to two series of three point running mean filters in order to reduce any noise in the form of large deviations between adjacent intervals if necessary. The interval containing the largest number of observations was assigned a value of one and each of the remaining intervals were given a value proportional to its relative occurrence.

For cover, a simple frequency bar histogram was constructed. The variate with the greatest number of observations was assigned a value of one and each remaining variate was assigned a value proportional to its relative occurrence.

Habitat use criteria for substrate were developed using two different techniques. Dominant substrate, subdominant substrate, and percent embedded in fines were analyzed separately for each species and lifestage. Frequency histograms were constructed for each component of substrate, with the greatest number of observations in an interval receiving a value of one with each remaining interval assigned a value proportional to its relative occurrence. All three of the resulting curves, dominant substrate, subdominant substrate, and percent embedded in fines, were plotted for each species and lifestage for easy comparison. For spawning lifestages of each species substrate was also analyzed using the Brusven index in its entirety. Again, the substrate category or interval with the greatest number of observations were assigned a value of one, and the remaining intervals were assigned a value proportional to their relative occurrence. Because the Brusven index is composed of three digit descripter there were a large number of different substrate compositions possible. As a result, since the distribution is discrete, there were a large number of intervals to work with when the frequency distribution was tabulated. With such a large number of possible combinations there were many incomplete sections in the resulting distribution, unless the data base was very large or the target species used a narrow or well defined range of substrate types. In this study only those substrates used by spawning salmon and trout were defined well enough to develop criteria with the Brusven index. A much larger data base would be necessary before the Brusven index could effectively be used to describe substrate utilization by fry and juvenile lifestages.

Analysis of available habitat data was conducted using the same methods described for analyzing habitat use data.

Preference criteria were computed with the following function:

$$P_i = \frac{U_i}{A_i}$$

where: P_i = an unnormalized index of preference at x_i

U_i = the relative frequency of fish observations at x_i

A_i = the relative frequency of available habitat at x_i

X_i = the interval of the variable (x)

Curve smoothing techniques were applied to those criteria which still exhibited large deviations between adjacent intervals that were thought not to represent actual behavior preferences. Resulting preference criteria were then normalized to values between 0.0 and 1.0.

RESULTS

A summary of data collection achieved by direct observation in the Trinity River is presented in Table 4. Use criteria for fry, juvenile, and spawning lifestages of chinook and coho salmon and steelhead trout are illustrated in Appendix A. A comparison between spawning use curves for mean water column velocity and fish nose velocity for chinook and coho salmon and steelhead trout is presented in Appendix B. Use of the Brusven index to describe substrate utilization for spawning salmon and steelhead trout produced criteria with some discrepancies. In an effort to reduce these inconsistencies I used a combination of professional judgment and running averages for each distribution. Appendix C contains both the untouched and adjusted substrate utilization criteria for spawning chinook and coho salmon and steelhead trout as described with the Brusven index.

Results of available habitat estimates for total depth, mean water column velocity, cover, and substrate for all study sites and sampled discharges is presented in Appendix D.

Table 4. Summary of habitat suitability data collected through direct observation in the Trinity River, California, 1985-1987.

Species	Life Stage	Number of Focal Point Observations	Number of Fish Observed
Chinook	Fry	389	5988
	Juvenile	345	6352
	Spawning	311	378
Coho	Fry	130	913
	Juvenile	81	813
	Spawning	107	206
Steelhead	Fry	33	117
	Juvenile	325	832
	Spawning	88	72

Figure 3 displays the percentage of observations which were made in surface turbulent water for fry and juvenile lifestages of chinook and coho salmon and steelhead trout. Juvenile chinook salmon exhibited an increased use of turbulent water as they grew. Coho salmon juveniles showed no significant shift in turbulent water use. This tended to reinforce the finding of coho salmon juveniles to use slow water habitats where no surface turbulence is found, such as backwaters and slow edge habitat types. The strongest shift in use of turbulent water was displayed by steelhead trout. Almost 16 % of the observations conducted on steelhead trout fry were found in turbulent water habitats, while 37.2 % of the observations on steelhead juveniles were conducted in turbulent water.

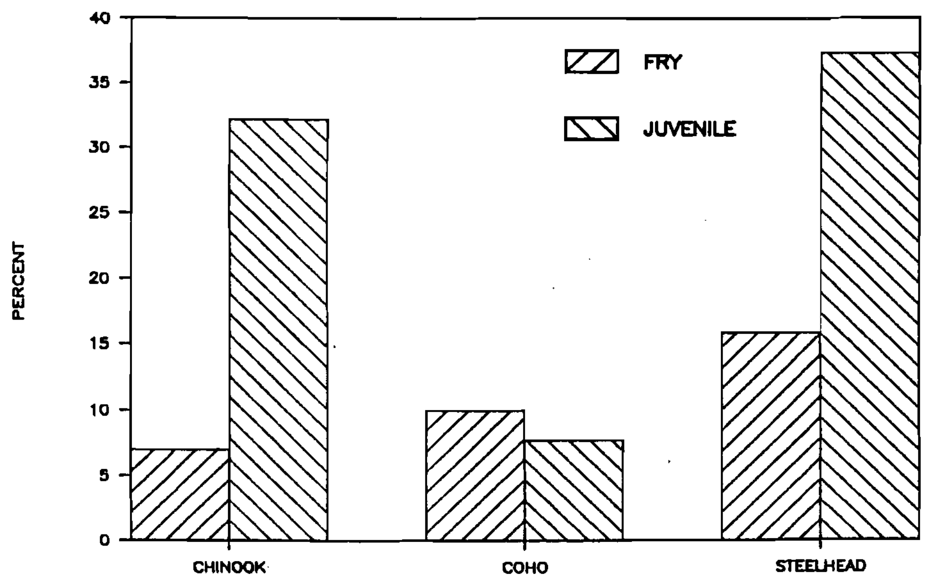


Figure 3. Percent of observations conducted on fry and juvenile chinook and coho salmon and steelhead trout that that were found in surface turbulence, Trinity River, California, 1985-1987.

During the fall months, when water temperatures fell below 48 - 50 degrees Fahrenheit, we found juvenile salmon and trout began to seek shelter by either burrowing under cobble substrates or concealing themselves in areas of thick cover, such as aquatic vegetation or woody debris. Direct observation of juvenile salmonids during these periods was largely unsuccessful. We soon discovered that the juvenile fish we were trying to observe could move through the interstitial substrate cavities at a much faster rate than we could dig through the substrate with our hands. Determination of focal point locations and species identification thus became virtually impossible to obtain under these conditions. As an alternate sampling method, a back pack electrofisher was used and worked well for locating juvenile salmonids in these over-wintering microhabitats. Use of an electrofisher as a microhabitat sampling tool does have some disadvantages. With a back pack electrofisher sampling is limited to habitats that are waist deep or less. There is also the possibility of herding fish away from their prefered holding locations thus biasing any results, however, when sampling during the winter months unwanted fish movement is limited because their focal points are located beneath cobble substrates were lateral movement is difficult. Substrates composed of cobbles and thick woody debris appeared to be one of the most important habitat variables present in our winter sampling of juvenile salmonids.

Preference criteria for fry, juvenile, and spawning chinook salmon is presented in Figures 4 through 9. Preference criteria for fry, juvenile, and spawning coho salmon is presented in Figures 10 through 15. Preference criteria were not developed for fry steelhead trout because the limited number of observations obtained were not felt adequate to describe the preference function with confidence. Preference criteria for juvenile and spawning steelhead trout is presented in Figures 16 through 19. An attempt was made to develop habitat preference criteria using the Brusven Index to describe preferred spawning substrates for chinook and coho salmon and steelhead trout, however, the resulting preference functions were incomplete, and did not present adequate results.

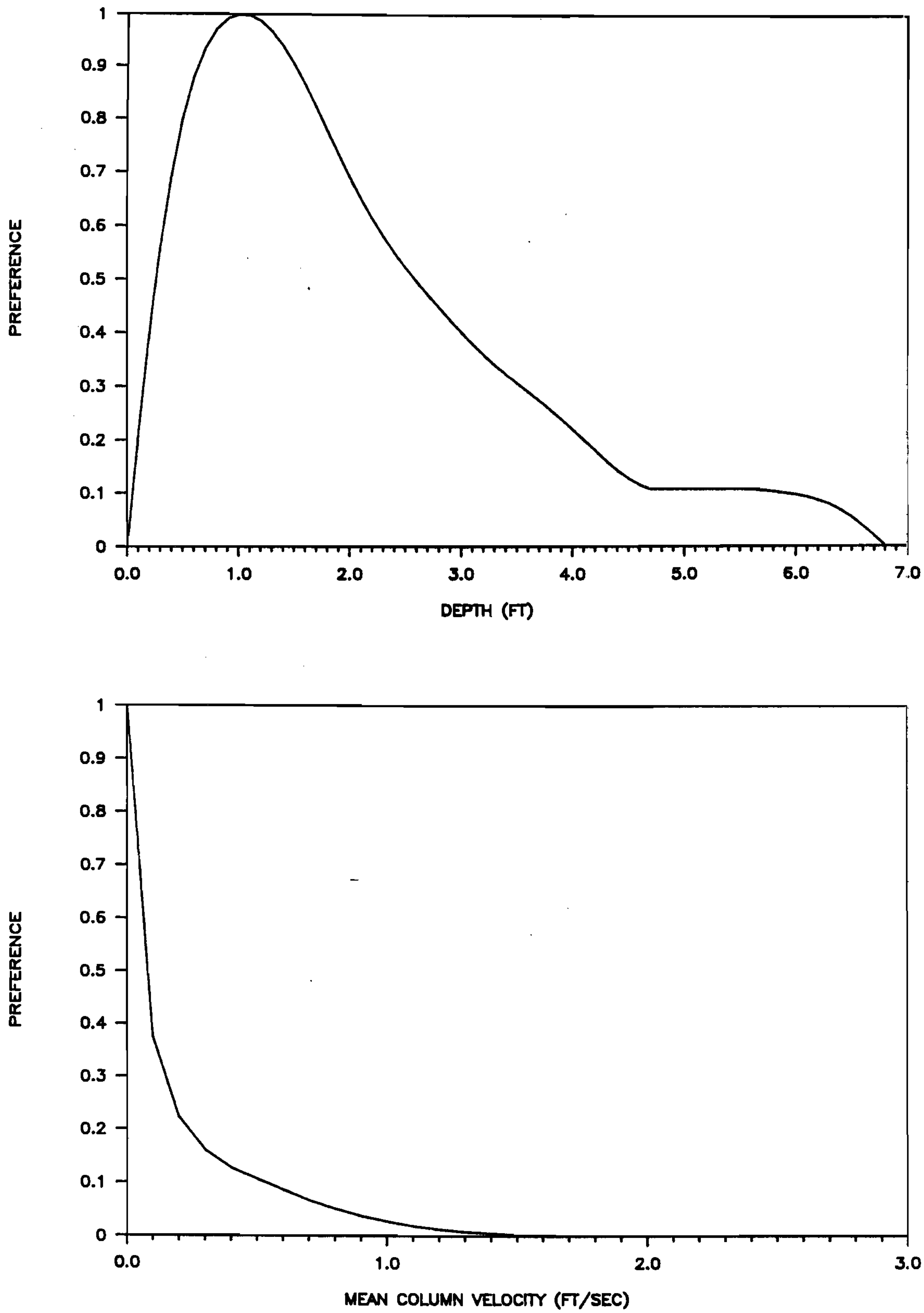


Figure 4. Habitat preference criteria for total depths and mean column velocities selected by chinook salmon fry in the upper Trinity River, CA., 1985-1987.

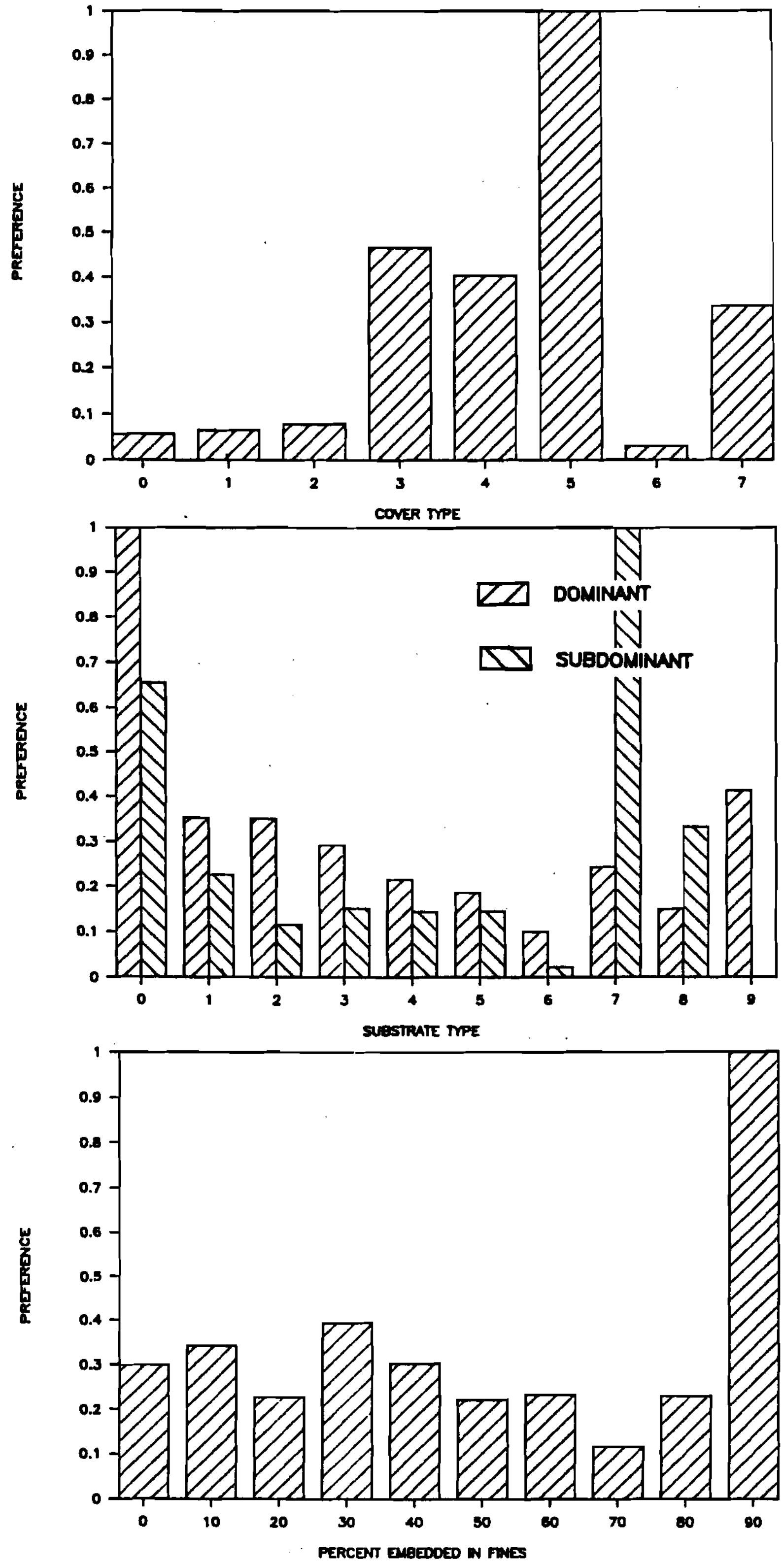


Figure 5. Habitat preference criteria for cover and substrates selected by chinook salmon fry in the upper Trinity River, CA., 1985-1987.

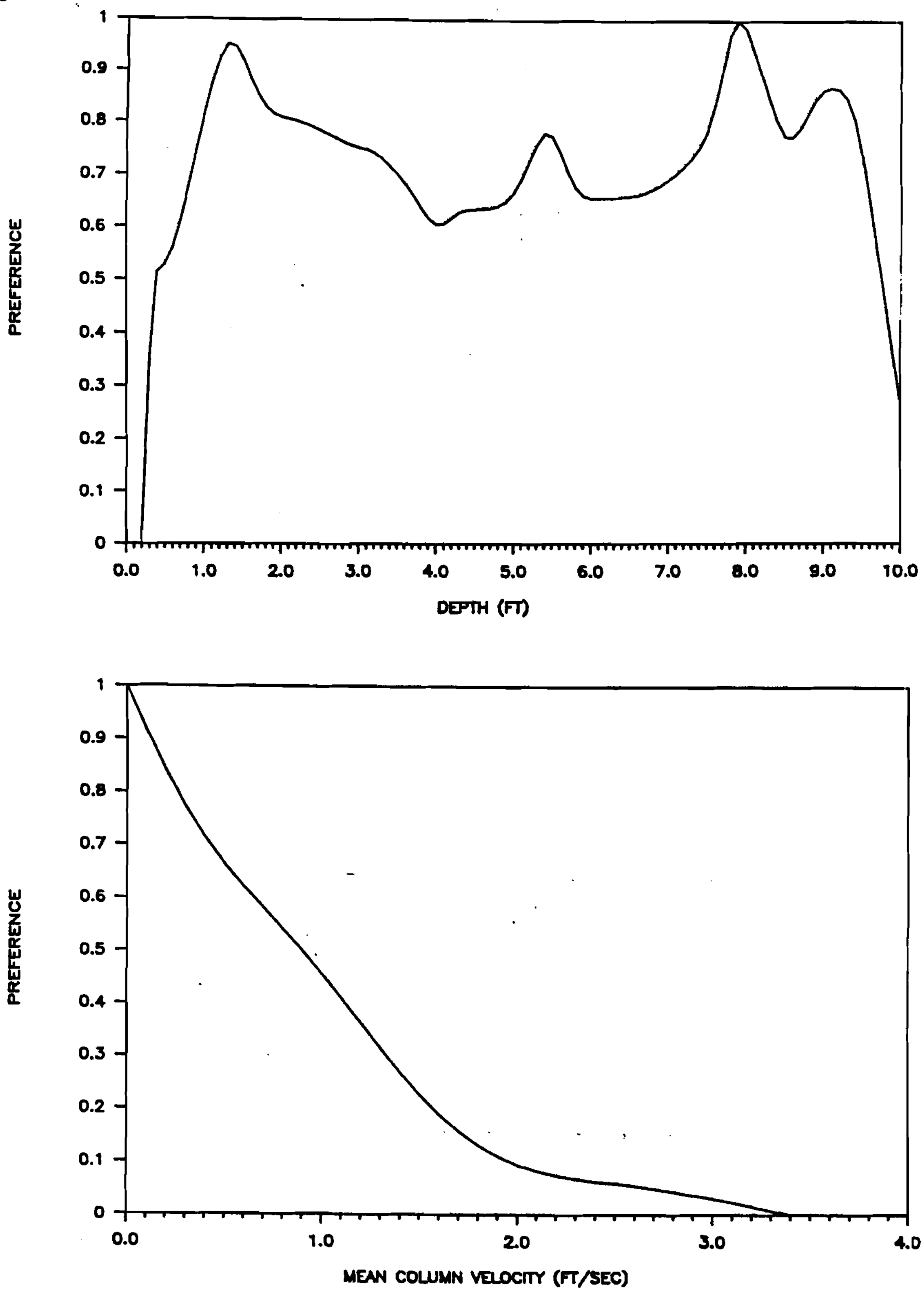


Figure 6. Habitat preference criteria for total depths and mean column velocites selected by chinook salmon juveniles in the upper Trinity River, CA., 1985-1987.

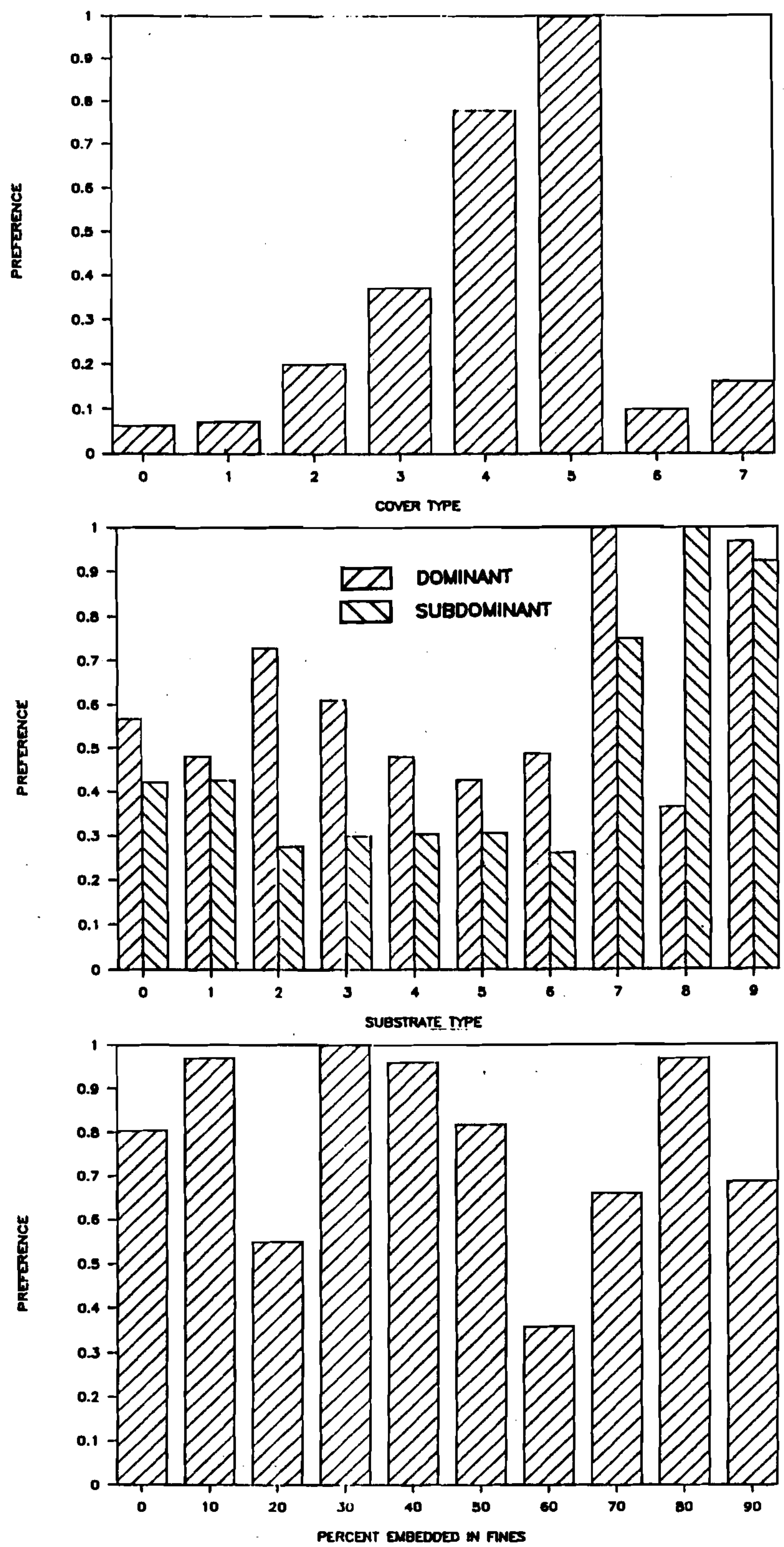


Figure 7. Habitat preference criteria for cover and substrates selected by chinook salmon juveniles in the upper Trinity River, CA., 1985-1987.

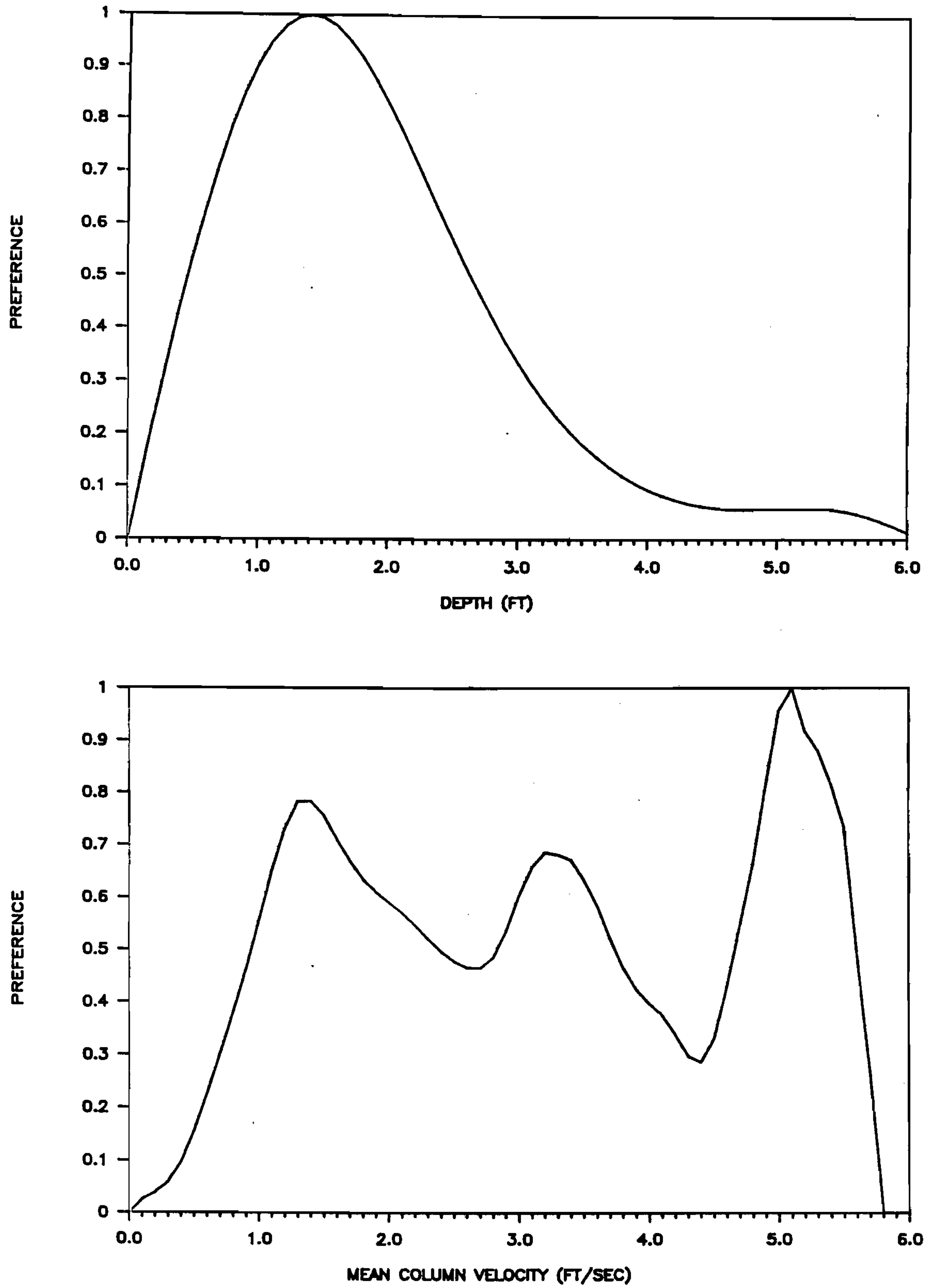


Figure 8. Habitat preference criteria for total depths and mean column velocities selected by spawning chinook salmon in the upper Trinity River, CA., 1985-1987.

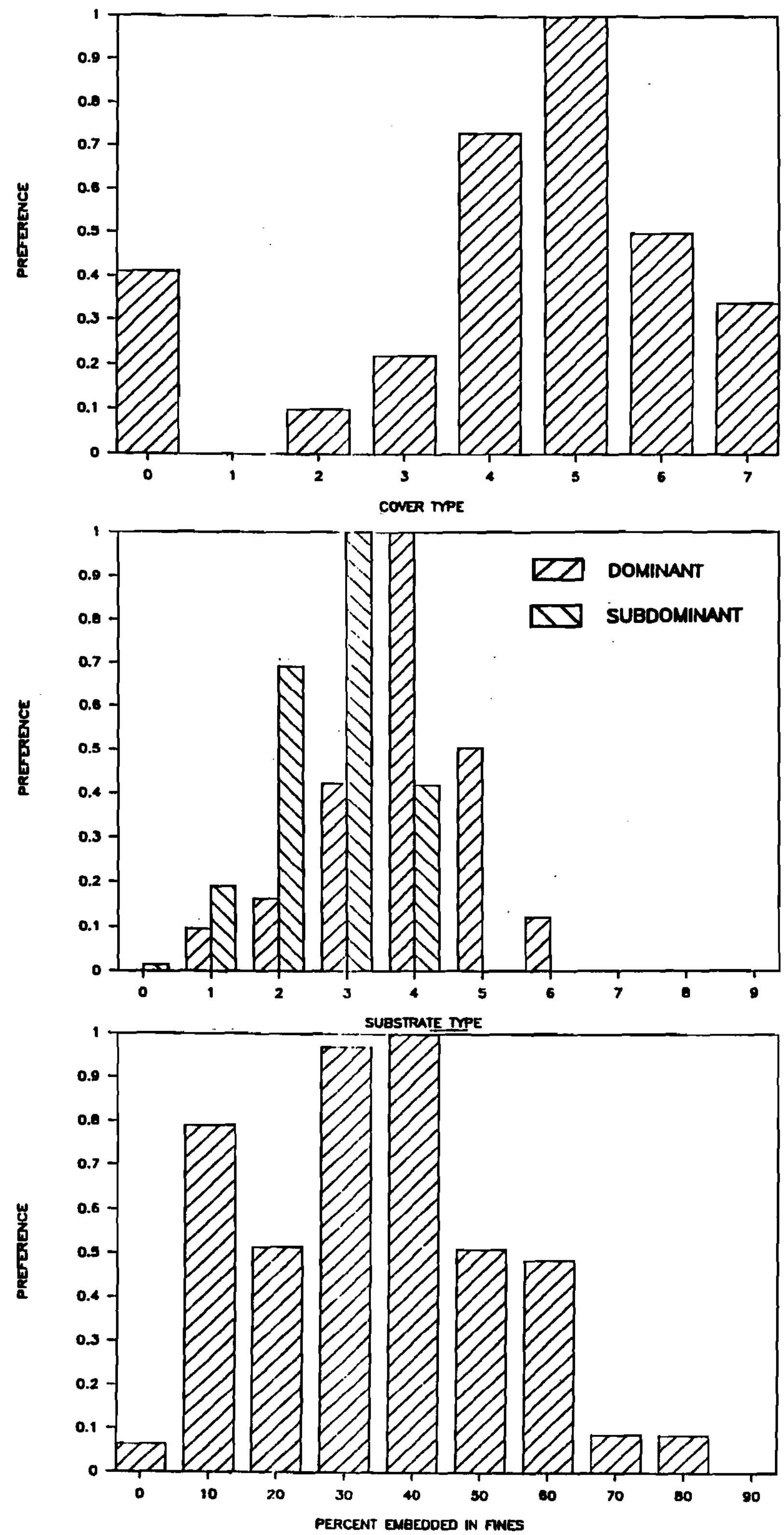


Figure 9. Habitat preference criteria for cover and substrates selected by spawning chinook salmon in the upper Trinity River, CA., 1985-1987.

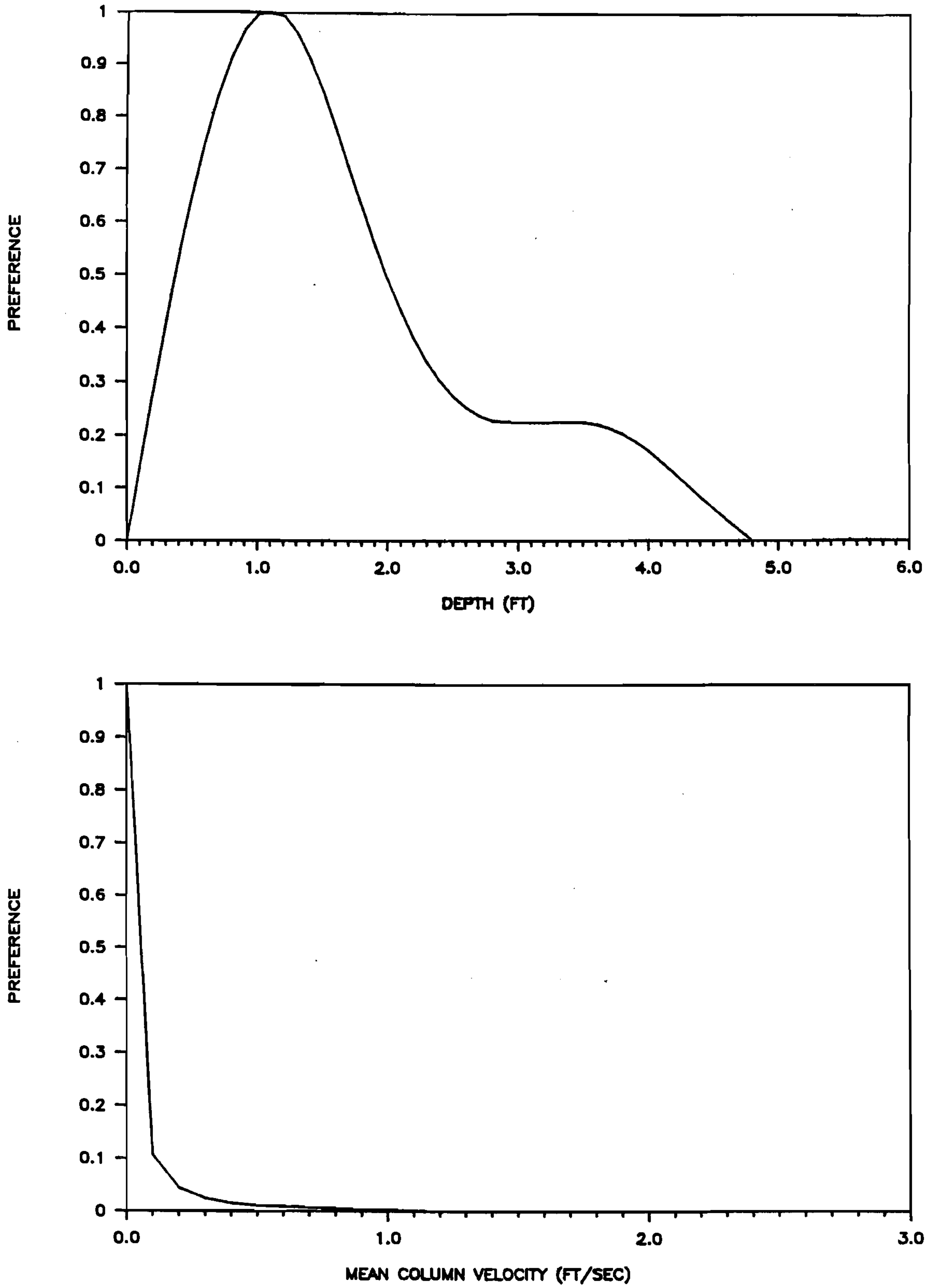


Figure 10. Habitat preference criteria for total depth and mean column velocities selected by coho salmon fry in the upper Trinity River, CA., 1985-1987.

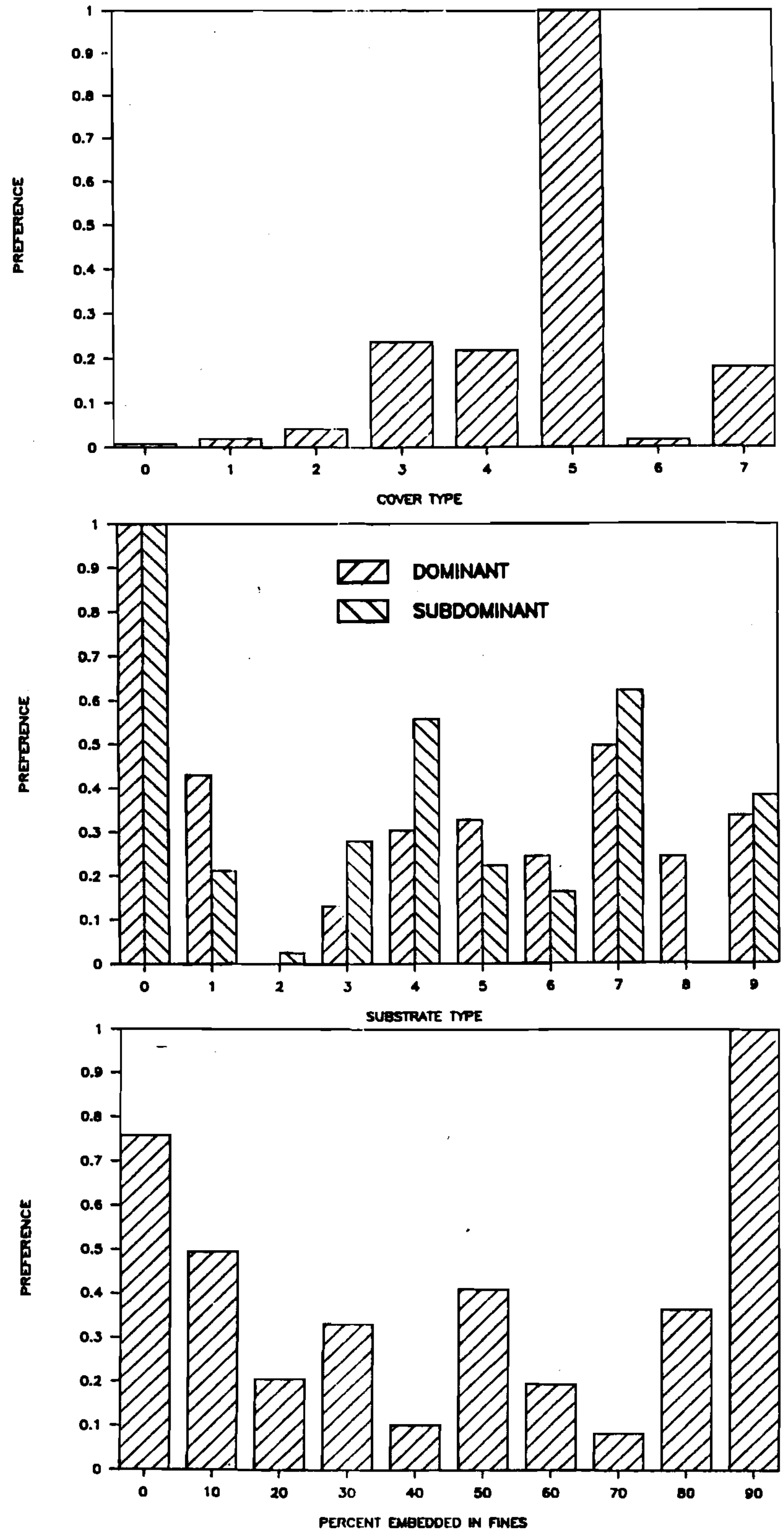


Figure 11. Habtat preference criteria for cover and substrates selected by coho salmon fry in the upper Trinity River, CA., 1985-1987.

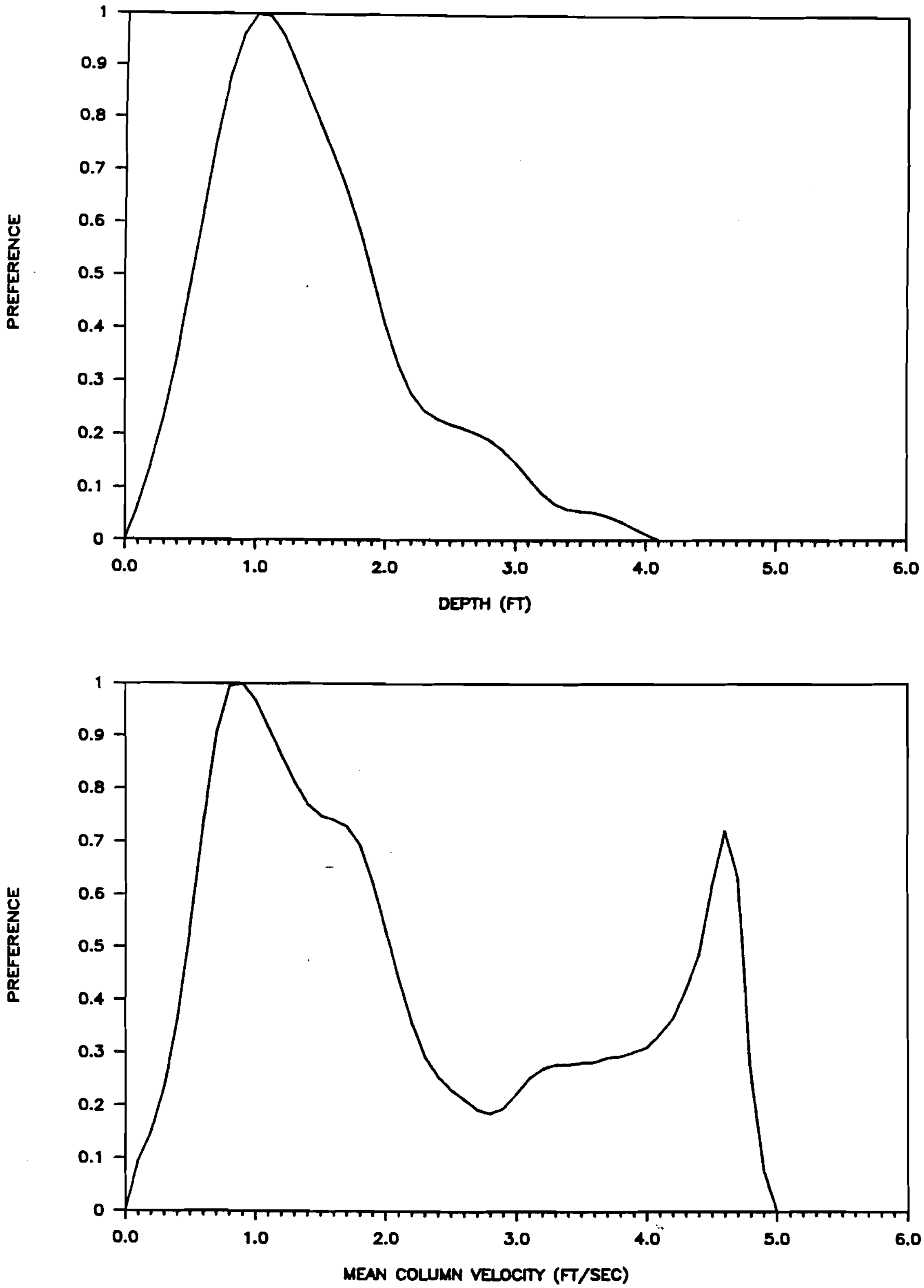


Figure 14. Habitat preference criteria for total depths and mean column velocities selected by spawning coho salmon in the upper Trinity River, CA., 1985-1987.

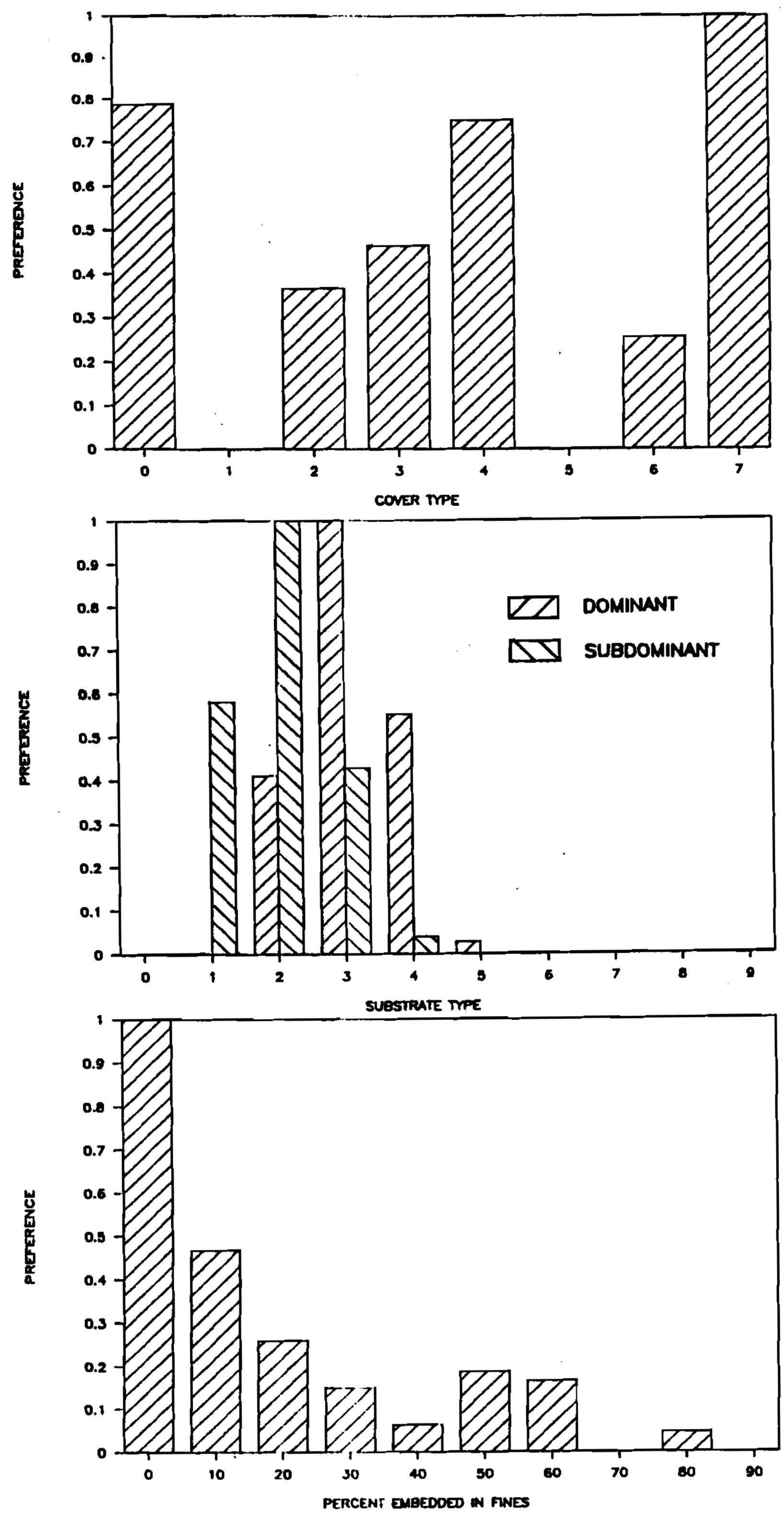
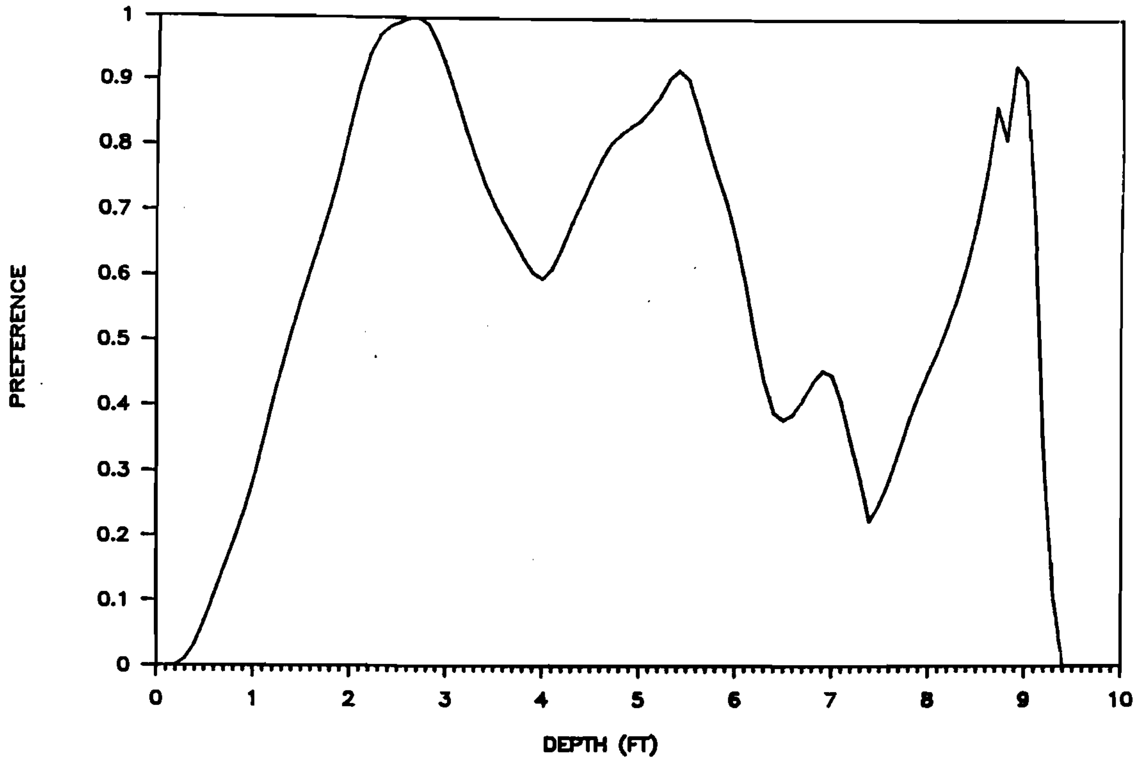


Figure 15. Habitat preference criteria for cover and substrates selected by spawning coho salmon in the upper Trinity River, CA., 1985-1987.



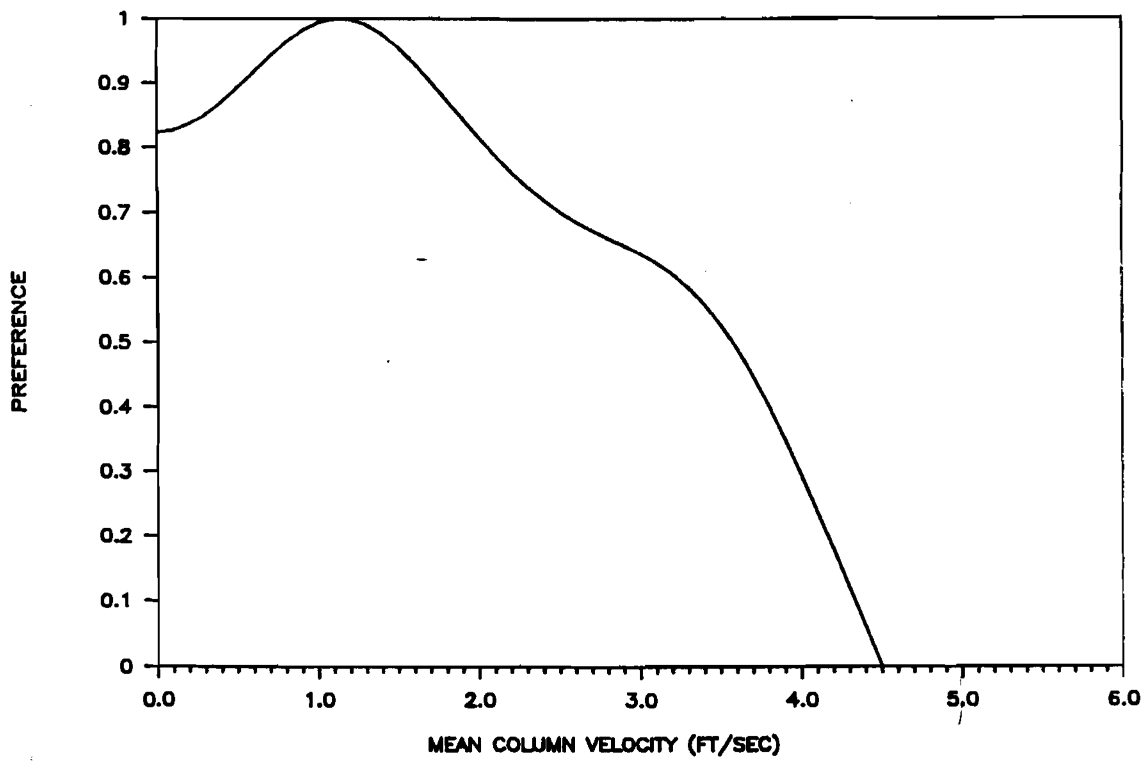


Figure 16. Habitat preference criteria for total depths and mean column velocities selected by steelhead trout juveniles in the upper Trinity River, CA., 1985-1987.

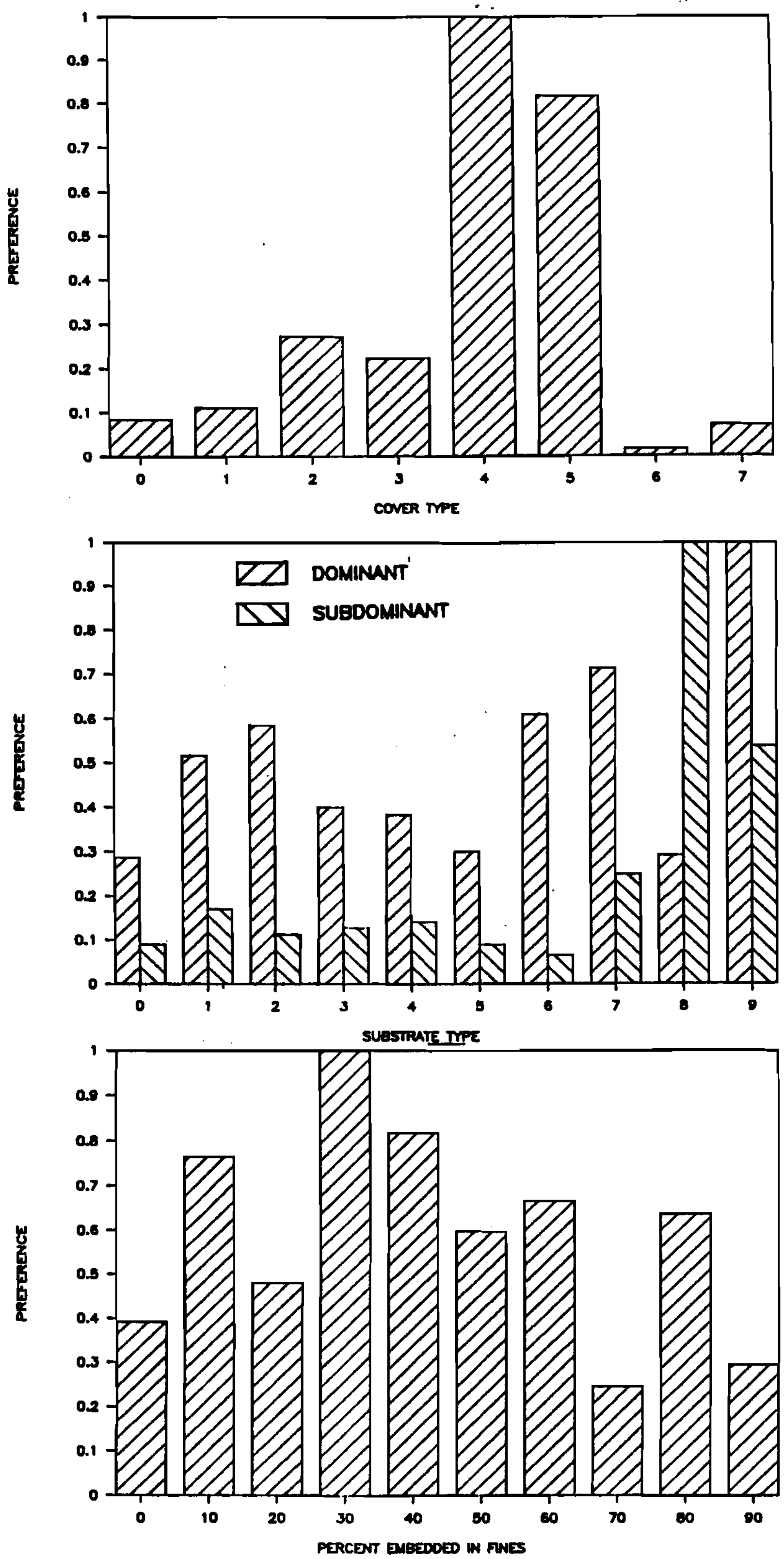


Figure 17. Habitat preference criteria for cover and substrates selected by steelhead trout juveniles in the upper Trinity River, CA., 1985-1987.

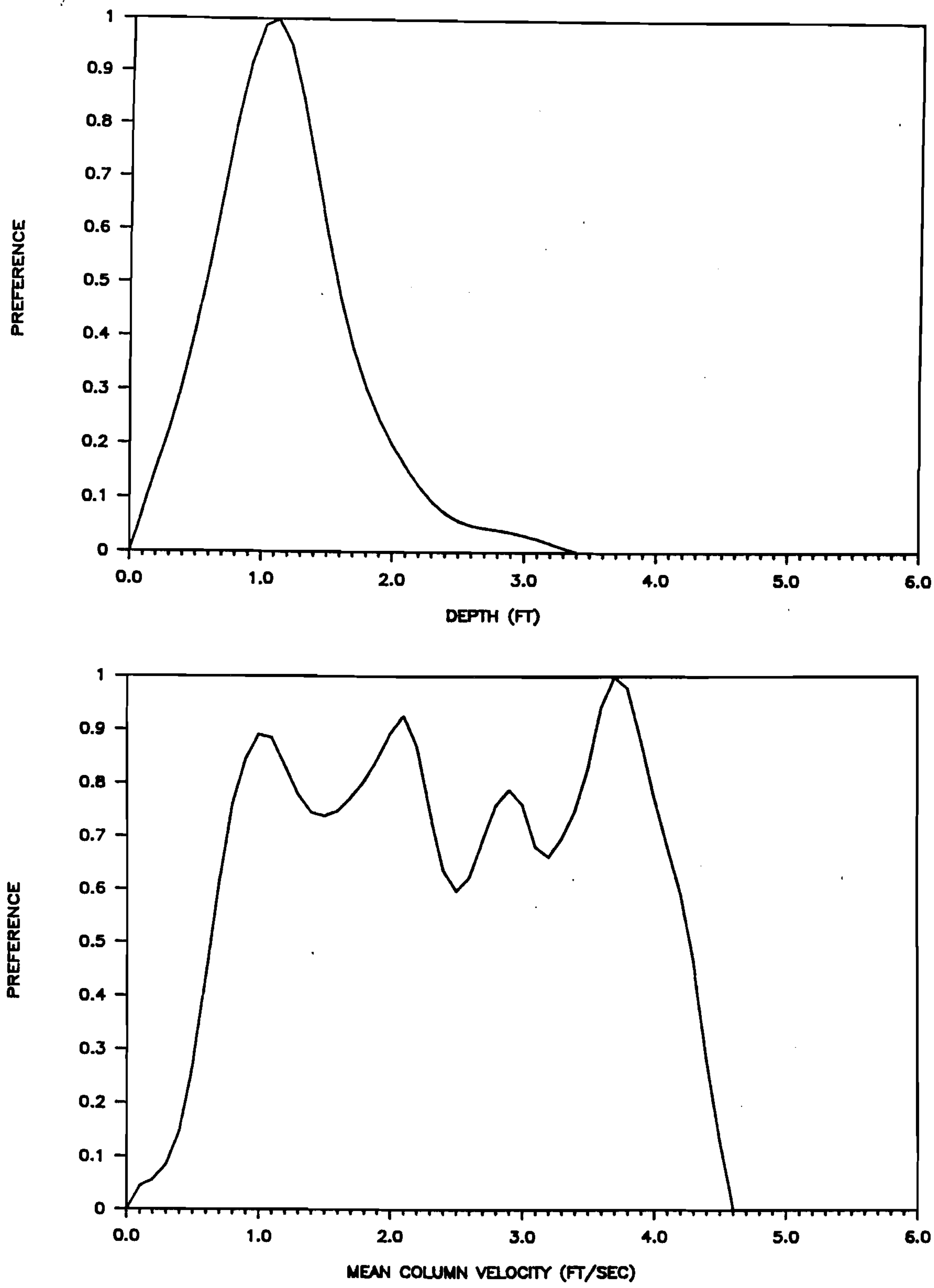


Figure 18. Habitat preference criteria for total depths and mean column velocites selected by spawning steelhead trout in the upper Trinity River, CA., 1985-1987.

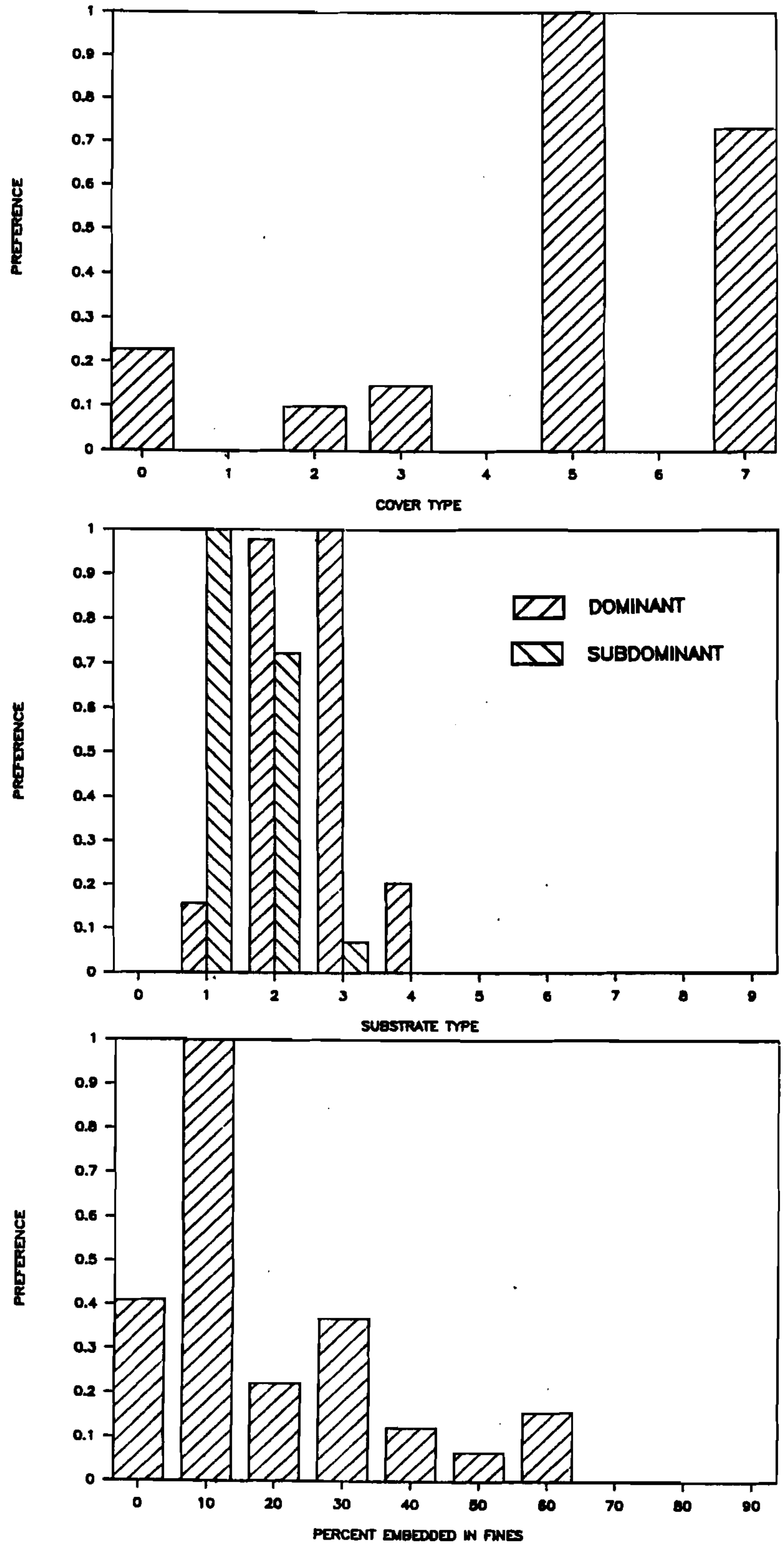


Figure 19. Habitat preference criteria for cover and substrates selected by spawning steelhead trout in the upper Trinity River, CA., 1985-1987.

DISCUSSION

A comparison between use criteria and preference criteria describing depths and mean column velocities selected by spawning chinook and coho salmon and steelhead trout is presented in Figure 20. Preference criteria describing mean column velocities preferred by chinook salmon and steelhead trout deviate significantly from the representative utilization criteria. The preference and utilization criteria developed on velocities chosen by coho salmon exhibit similar suitabilities until velocities begin to exceed 2.8 feet per second, at which point preference values start to increase rapidly and utilization values decrease into the tail end of the distribution. For all three species, high preference values correspond with low utilization values located in the upper limits of each utilization distribution where high water velocities are present. A closer examination of the spawning velocity use data revealed the source of these high preference values. When mean column water velocities begin to exceed about 3.0 feet per second, both the utilization and availability distributions begin to approach zero. This resulted in small probability ratios for both utilization and preference as can be expected, however, the ratio between use and availability ($P_i = U_i/A_i$) remained fairly large. Therefore, a large preference value resulted. In this situation it appears that the behavioral selection of one individual within the population yielded a misrepresentation of the actual preference for the majority of the population. When both the use and availability distributions simultaneously enter the limits of their distributions there is a danger of misrepresenting actual preference simply because of small probability ratios involved. In these instances it is important that the investigator has a good understanding for the species under study so that any extraneous preference values can be recognized and corrected. In order to eliminate the influence of these outliers within the spawning velocity distributions for each species, I applied nonparametric tolerance limits to each frequency distribution which would include 90% of the use observations at a 90% confidence level. Tolerance limits were obtained from a table developed by Somerville as presented by Bovee (1986). Utilization and preference criteria were then recalculated using those frequency values that fell within the 90% tolerance levels established. A comparison of adjusted preference criteria for spawning velocities with the original preference criteria developed is presented in Figure 21. The adjusted preference criteria for spawning velocities selected by salmonids in the Trinity River compare favorably with utilization criteria developed for spawning velocities actually used and probably represent a more accurate description of true preference.

Habitat preference criteria describing depth selection for juvenile chinook salmon and steelhead trout fluctuate

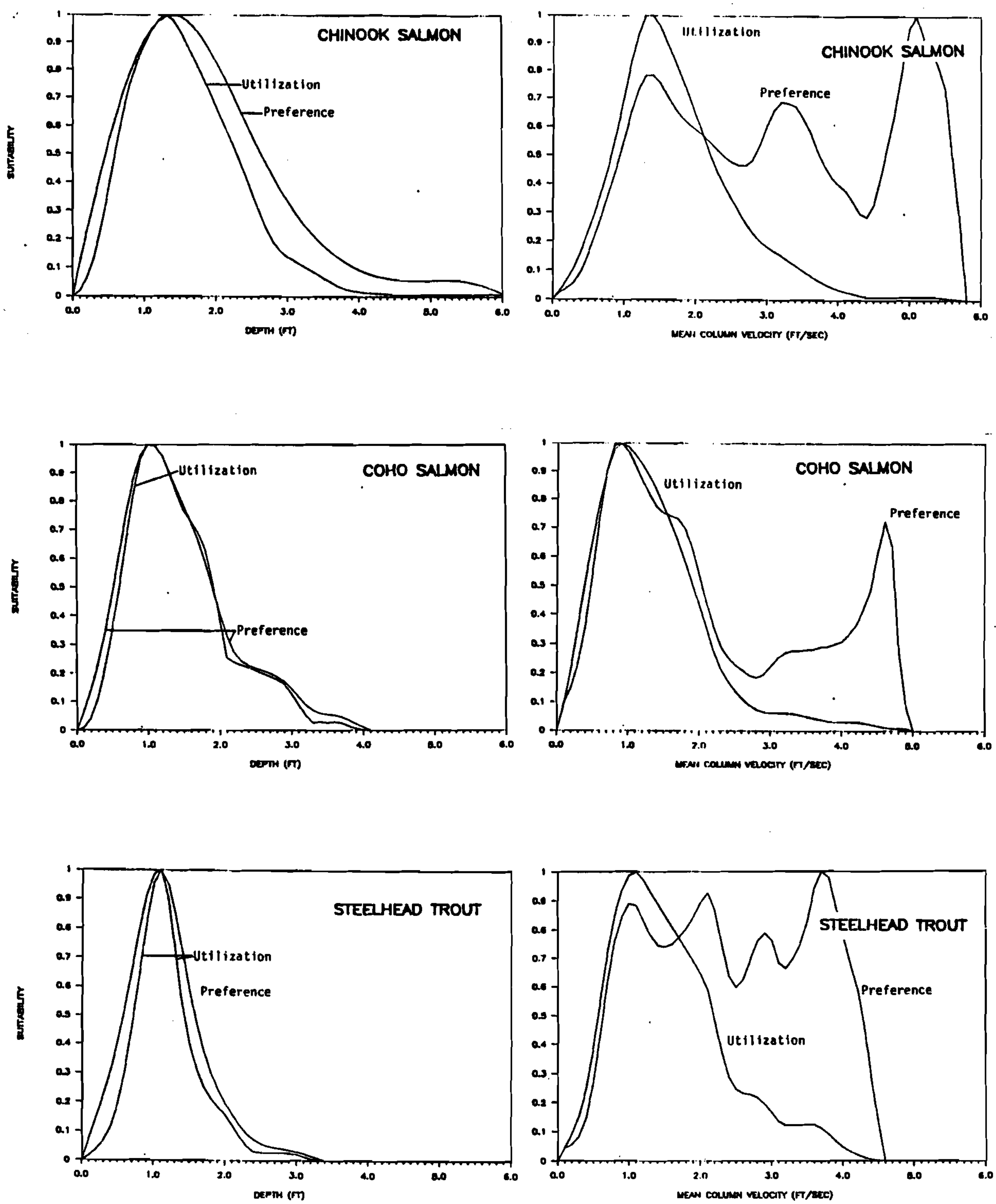


Figure 20. Habitat use and preference criteria for total depth and mean column velocity for spawning chinook and coho salmon and steelhead trout in the upper Trinity River, CA., 1985-1987.

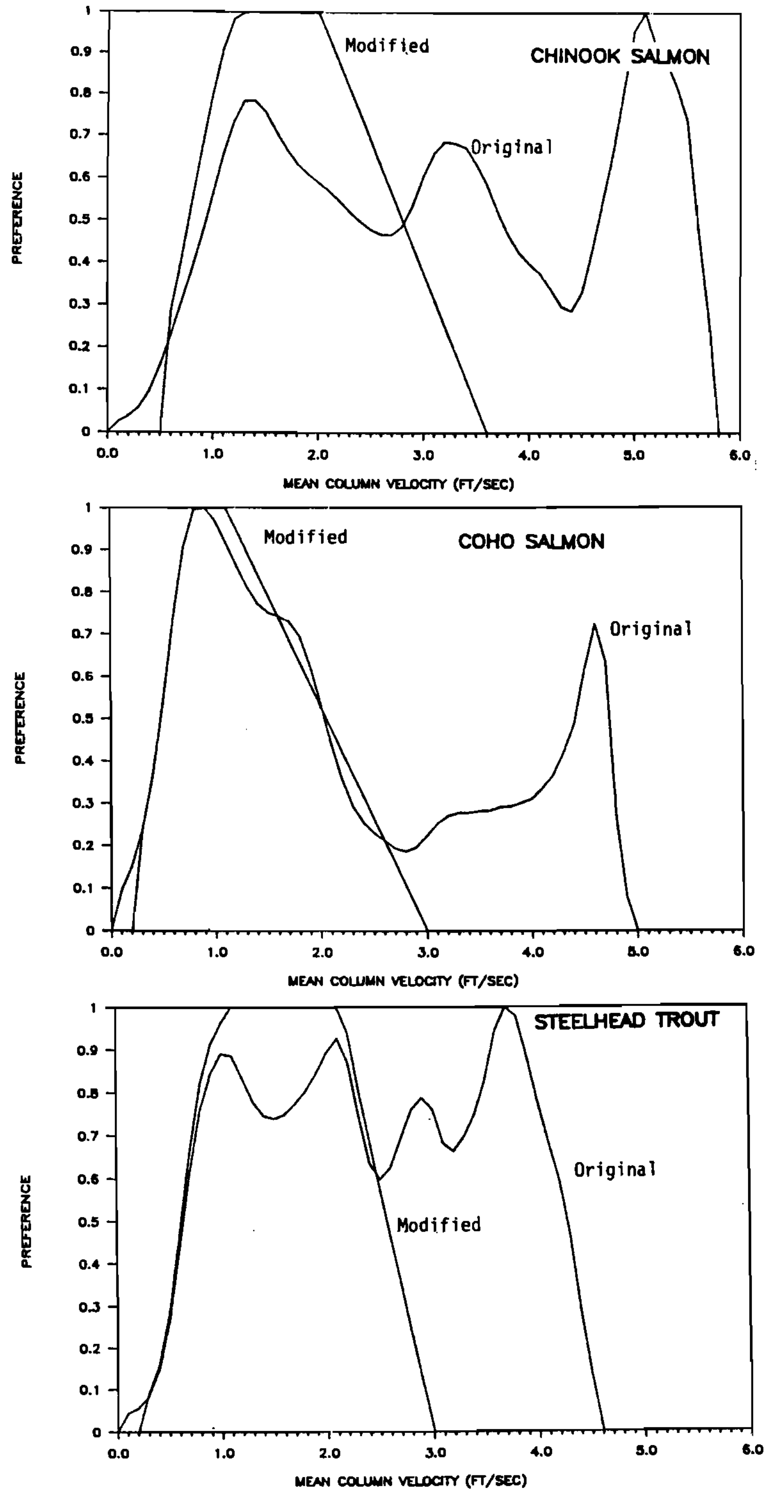


Figure 21. Original preference criteria and modified preference criteria, developed from use data after 90% tolerance limits were applied, for mean column velocities selected by spawning anadromous salmonids in the upper Trinity River, CA., 1985-1987.

greatly. It appears that juvenile chinook salmon and steelhead trout do not exhibit a strong preference for a particular depth range. Observations in the field have led me to believe that water velocity is the critical hydraulic parameter that determines final microhabitat selection for these two species and lifestages during the spring, summer, and early fall months. This would explain the wide range of depths that are described by the final preference criteria. Figure 22 presents modifications to depth preference criteria for juvenile chinook salmon and steelhead trout that were made by professional judgment.

Trinity River chinook salmon are composed of two major stocks, the spring and fall runs. The spring run chinook ascend the river on their spawning migration from April through October, with the majority of fish reaching the upper river by the end of July. The fall run chinook migration begins in September and continues into November. Moffett and Smith (1950) described three distinct seasonal migrations of chinook salmon past Lewiston before the Trinity River Division of the Central Valley Project was built. A spring run past Lewiston in June and July, A summer run in August and September, and the fall run from October to November. The spring and summer fish spawned between Grass Valley Creek and Stuarts Fork in early October and by mid-October spawning spread from the North Fork Trinity River upstream to The East Fork Trinity River. The fall run fish spawned later usually after the early fall freshets had increased river flow opening up new spawning areas further upstream where spring and summer run adults were unable to reach. Under historic uncontrolled flow conditions these differences in the time of spawning provided spatial segregation through increased habitat gains further upstream as a result of higher flows. Under the current controlled flow management scheme the only mechanism for maintaining the genetic integrity between the two runs is time of spawning, in which some overlap does occur. With the presence of Lewiston Dam and controlled flow, the habitat areas available to each run are equal. As a result, the available spawning areas below Lewiston Dam experience heavy use by both runs of chinook salmon and by coho salmon and steelhead trout. This constant pressure on the available habitat leads to a large percentage of superimposition of redds throughout the spawning season. I chose not to develop separate habitat suitability criteria for the spring and fall runs of chinook salmon, since the habitat available to each run is equal.

Spawning chinook salmon in the Trinity River preferred mean column velocities from 1.2 to 2.0 feet per second, in water 1.4 feet deep. Category I criteria developed by Bovee (1978) for spawning chinook salmon suggested a range of optimum mean column velocities from 1.0 to 1.7 feet per second in depths from 0.8 to 1.0 feet for spring run chinook and mean column velocities from 1.5 to 1.7 feet per second and depths from 0.7 to 1.0 feet for fall run chinook. Raleigh et al. (1986)

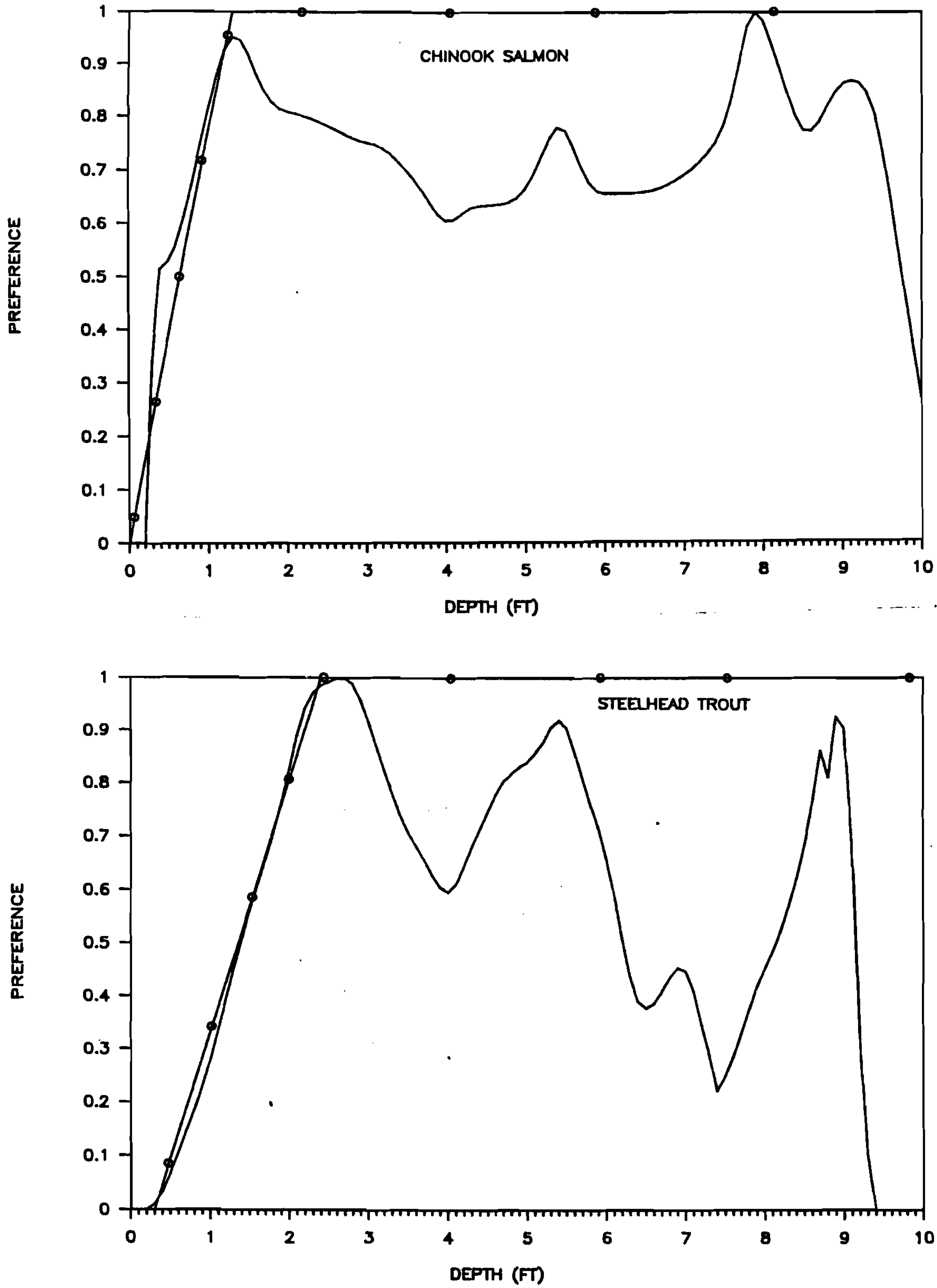
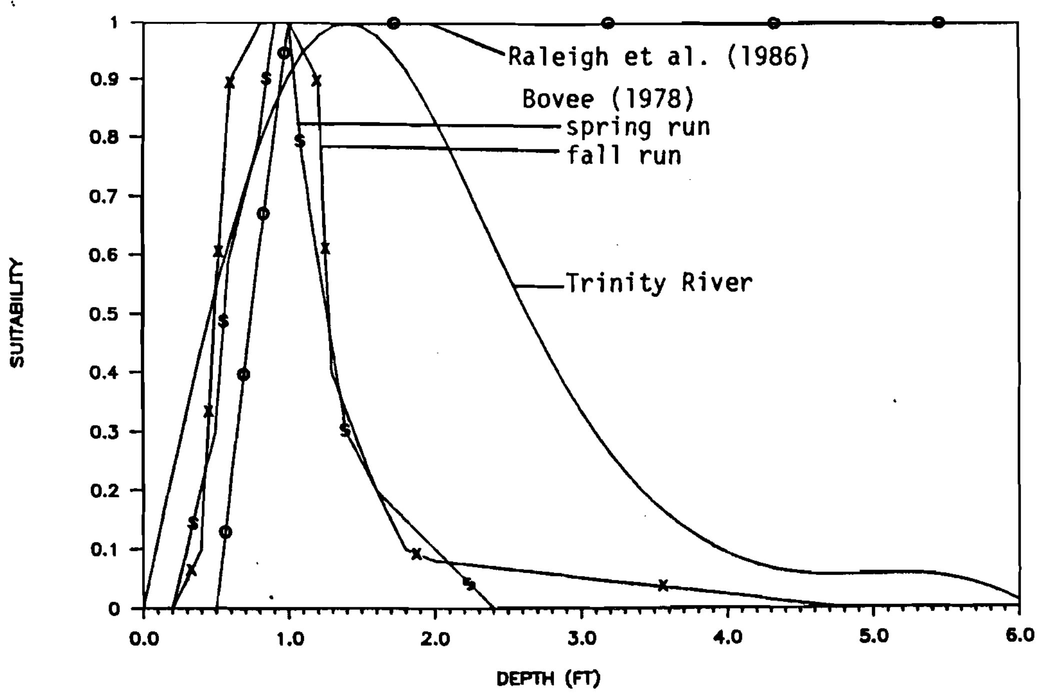


Figure 22. Original (——) and modified (—•—) preference criteria for total depths selected by chinook salmon and steelhead trout juveniles in the upper Trinity River, CA., 1985-1987.

developed category I criteria presenting optimum mean column velocities from 1.5 to 2.4 feet per second and optimum depths as 1.0 feet or greater (Figure 23). A comparison of preference criteria developed in this study with published use criteria describing mean column velocities selected by spawning chinook salmon is present in Figure 24. Trinity River chinook salmon preferred comparable mean column velocities with use criteria reported by other researchers with the exception of use criteria reported by Stempel (1984). On the Yakima River, Stempel found that mean water column velocities from 1.9 to 2.8 feet per second provided the greatest suitability for spawning spring chinook salmon averaging from 85 -100 cm in length. This compares with mean column velocities from 1.2 to 2.0 feet per second that were preferred by spawning chinook salmon in the Trinity River. A comparison of use criteria developed for nose velocities selected by spawning chinook salmon in the Trinity River with use criteria developed by Vogel (1982) and Kurko (1977) is presented in Figure 25. Vogel and Kurko measured nose velocities at 0.5 feet. Spawning chinook salmon in the Trinity River selected the slowest nose velocities. These differences in selection may be a factor of sampling methods, equipment used, fish size or behavior differences that exist.

Trinity River chinook salmon have historically been recognized as physically smaller in size. Average fork lengths of returning adult chinook salmon to Trinity River Hatchery are presented in Figure 26. Physically smaller adults may account for selection of slower water velocities for redd construction by Trinity River chinook salmon. Mills (pers. comm.) measured nose velocities at 0.4 feet and found that spawning fall chinook salmon in the South Fork Trinity River most often selected nose velocities of 2.1 feet per second. The reasons for the discrepancies between nose velocities selected by South Fork Trinity River and mainstem Trinity River chinook salmon may be an artifact of habitat availability differences between the two rivers. The South Fork Trinity River still exhibits a natural flow regime and has many wide point bars. The mainstem Trinity River has experienced several years of reduced controlled flow which allowed riparion vegetation to encroach along the banks eliminating these habitat types.



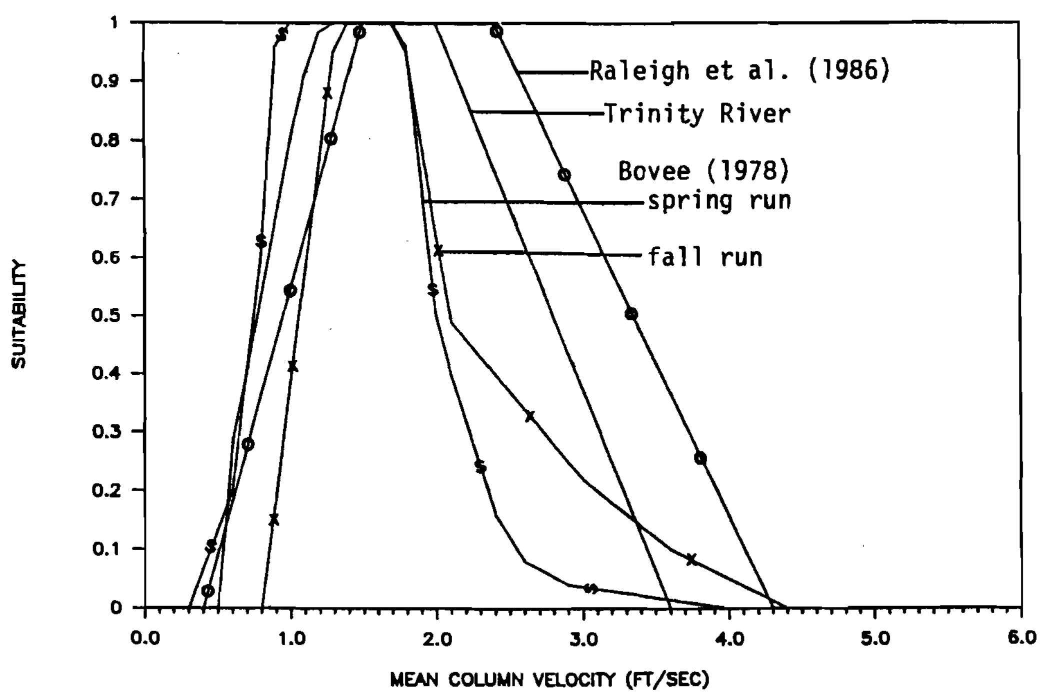


Figure 23. A comparison of preference criteria developed in the upper Trinity River with Category I criteria developed by Bovee (1978) and Ralêigh et al. (1986) for spawning chinook salmon.

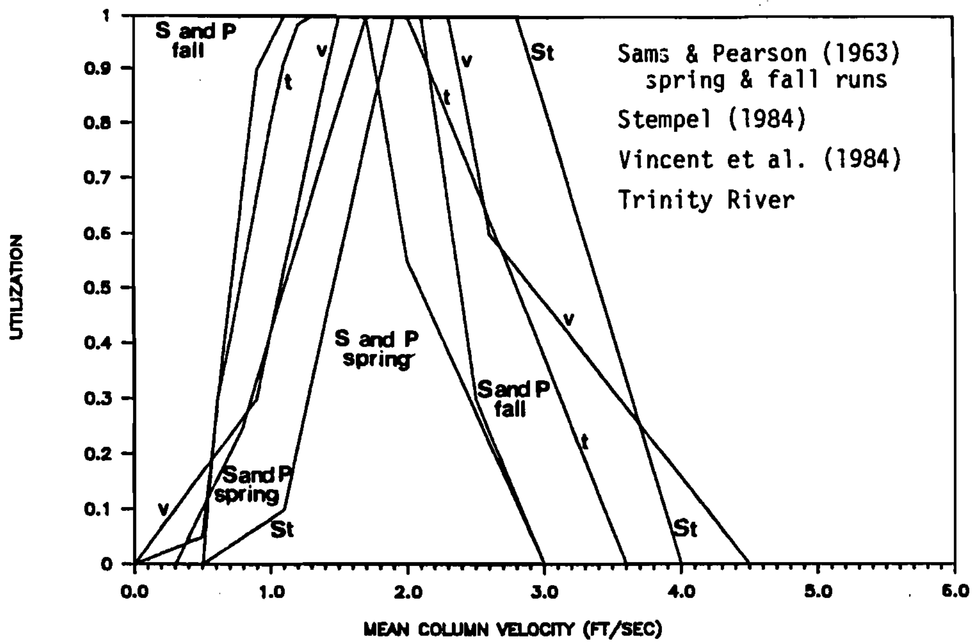


Figure 24. A comparison between preference criteria developed in the upper Trinity River with use criteria developed by other researchers for mean column velocities selected by spawning chinook salmon.

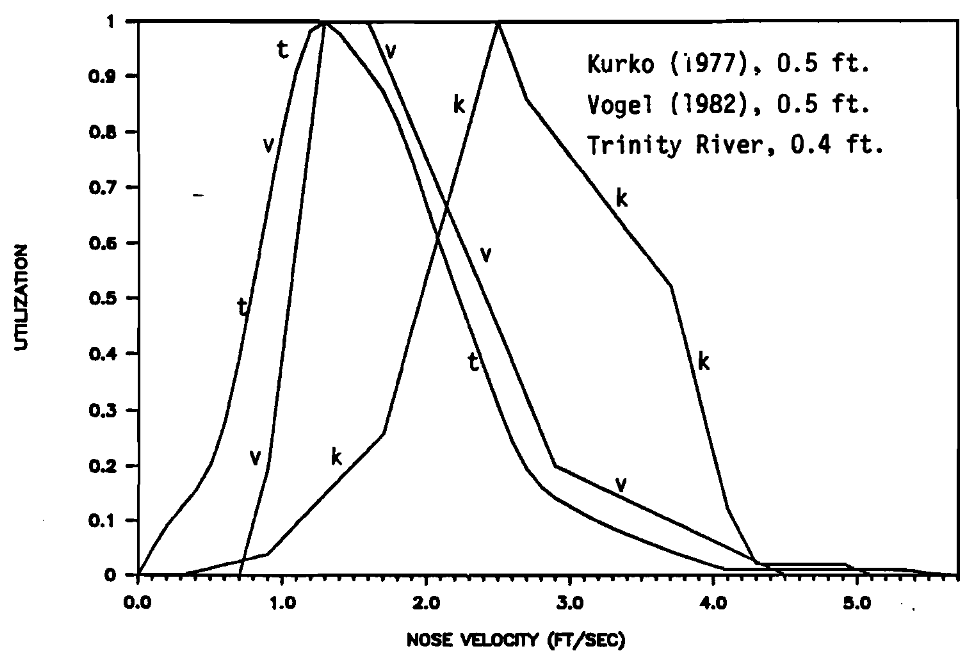


Figure 25. A comparison between use criteria of fish nose velocities selected by spawning chinook salmon in the upper Trinity River with spawning chinook salmon observed by other researchers.

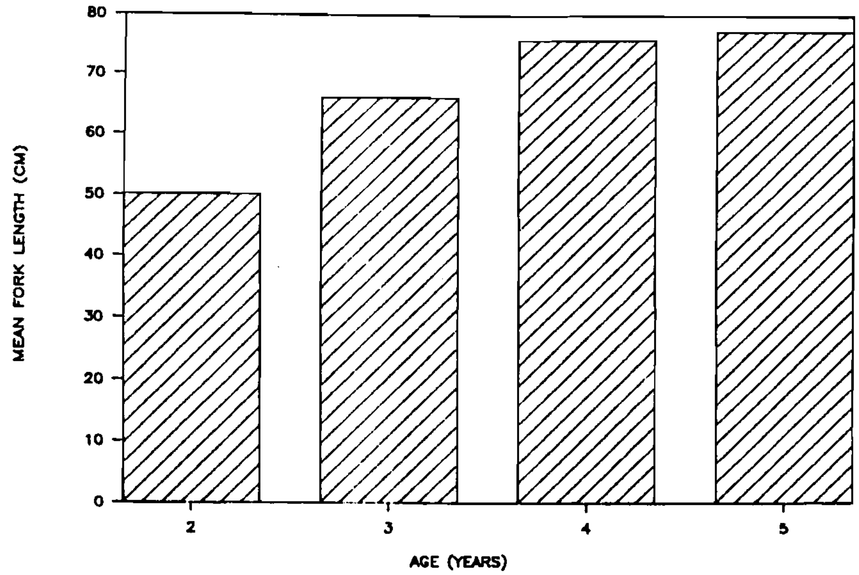


Figure 26. Mean fork lengths of tagged adult chinook salmon that returned to Trinity River Hatchery in 1985, California Department of Fish and Game, Trinity Co., California.

Adult coho salmon begin their migration up the Trinity River in October and spawning activity occurs from November through January. The majority of coho salmon that spawn in the mainstem do so in the upper reaches directly below Lewiston Dam. Spawning coho salmon preferred microhabitats containing mean column water velocities from 0.9 to 1.1 feet per second in water depths of 1.0 to 1.1 feet. Bovee (1978) presents category I criteria for spawning coho salmon as optimum for mean column velocities from 1.2 to 1.4 feet per second and depths from 0.6 to 0.8 feet (Figure 27). Trinity River coho salmon preferred slower velocities and slightly deeper water for spawning than the category I criteria provided by Bovee (1978).

Collection of habitat use data for adult steelhead trout was complicated by poor sampling conditions and low escapement levels. Adult steelhead migration occurs from November through April when winter storms commonly cause high river flows and turbidity levels which prevent effective sampling by direct observation. Returns of adult steelhead to Trinity Hatchery during the sampling period from 1985 through 1987 were 142, 461, and 3,780 respectively. The presence of a fairly good run in 1987, combined with good sampling conditions gave us the opportunity to obtain enough spawning data to develop utilization and preference criteria. Steelhead trout preferred mean column velocities from 1.1 to 2.1 feet per second in depths from 1.0 to 1.1 feet for spawning.

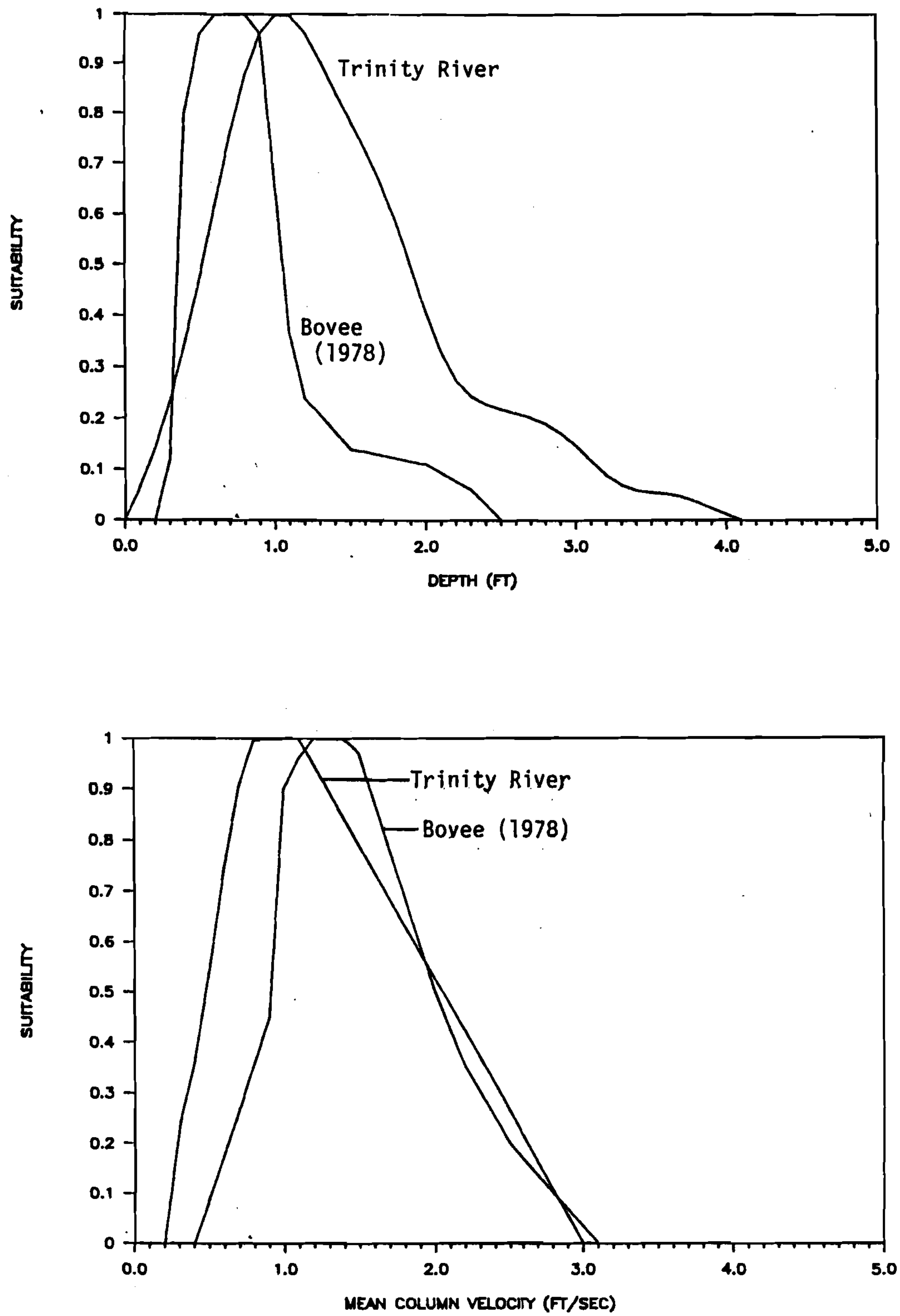


Figure 27. A comparison of preference criteria developed in the upper Trinity River with category I criteria developed by Bovee (1978) for spawning coho salmon.

Emergence of fry chinook salmon begins in December and continues into Mid-April (Leidy and Leidy, 1984). This lengthy timing in emergence accounted for large differences in size within chinook salmon observed during the Spring months. After emergence, fry chinook salmon occupied stream margins where slow velocities and abundant cover types were present. Woody debris, cobble substrates clear of fine sediments, and undercut banks provided critical escape cover from surface feeding predators, such as herons and mergansers. Preference criteria developed for fry chinook salmon showed optimum suitability for water 1.0 feet deep in mean column velocities of 0.0 feet per second. Utilization criteria developed for fry chinook salmon showed heaviest use of water depths from 1.2 to 1.3 feet also in zero velocity water. Category I criteria developed by Raleigh et al. (1986) show optimum habitat for fry chinook salmon as depths from 0.9 to 2.0 feet with mean column water velocities 0.2 to 0.3 feet per second (Figure 28). Burger et al. (1982) developed use criteria describing mean column velocities used by fry chinook salmon in Alaska and found that the greatest use occurred in 0.1 feet per second. Category I criteria developed by USFWS (1985) present depths from 0.7 to 1.0 feet as most suitable for fry chinook salmon. Trinity River fry chinook salmon preferred slower velocities and similiar depths as chinook salmon fry reported by other researchers.

As chinook salmon grew larger they became less dependent on stream margins and began to use areas with faster velocities in deeper water. Object cover in the form of fallen alders or willows were heavily utilized, both as protection from predators and as velocity shelters. A comparison of use criteria developed for juvenile chinook salmon on the Trinity River with category I criteria developed by Bovee (1978) and Raleigh et al. (1986) is presented in Figure 29. Juvenile chinook salmon in the Trinity River utilized similar depths and slower velocities as those presented by both Bovee (1978) and Raleigh et al. (1986). Stempel (1984) found that juvenile chinook salmon in the Yakima river basin selected depths from 2.3 to 2.7 feet with mean column velocities ranging from 0.4 to 0.5 feet per second. Chinook salmon juveniles on the Trinity River preferred slow water habitat in depths greater than 1.0 feet. Field observations confirm the importance of velocity as the determining factor in habitat selection over total depth by juvenile chinook salmon. Juvenile chinook salmon were observed in a wide range of depths as long as slow water velocities were available. Substrate only appeared to be an important factor for habitat selection when large cobbles or boulders could be used as velocity shelters in riffles and runs. In deep pool habitats, schools of juvenile chinook salmon positioned themselves in relationship to ever changing eddies and shear velocity zones where food items could be easily taken in the drift. In pools, the majority of juvenile salmon would feed near the water surface and would flee to deep water when frightened from above. At night fry and juvenile chinook

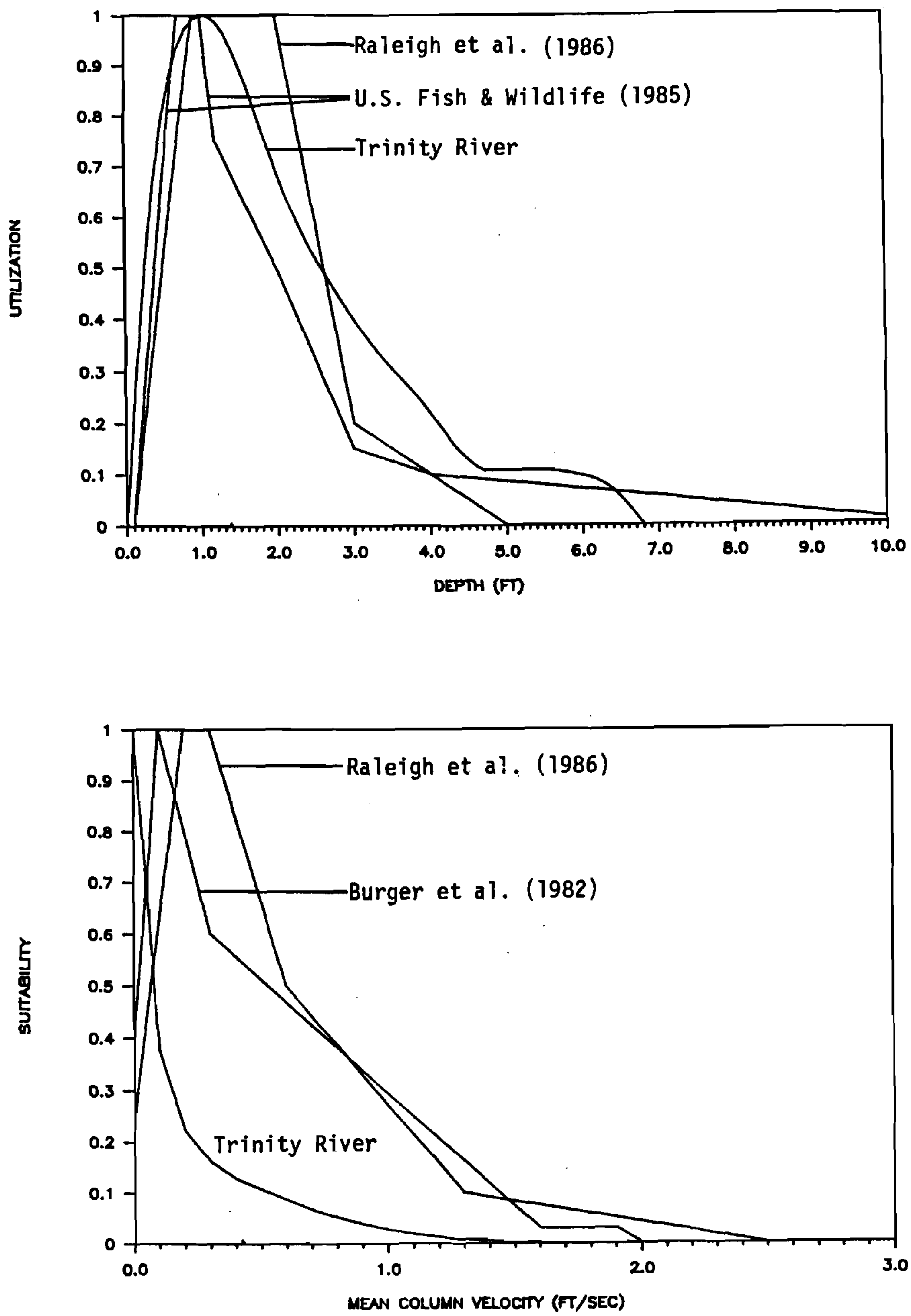
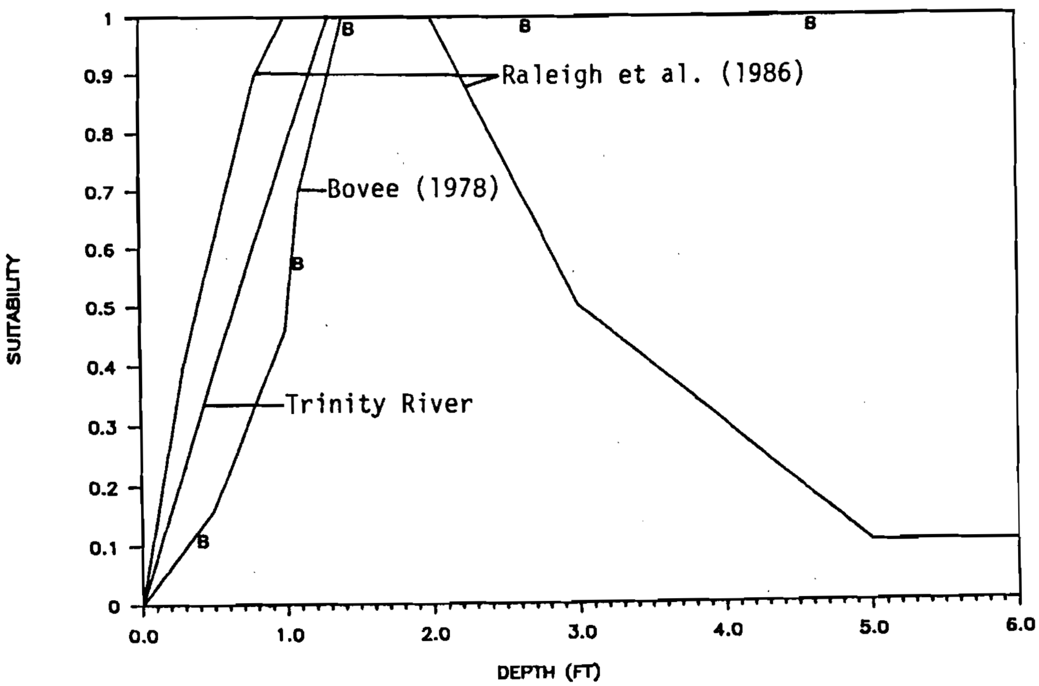


Figure 28. A comparison of preference criteria developed in the upper Trinity River with suitability criteria developed by other researchers for chinook salmon fry.



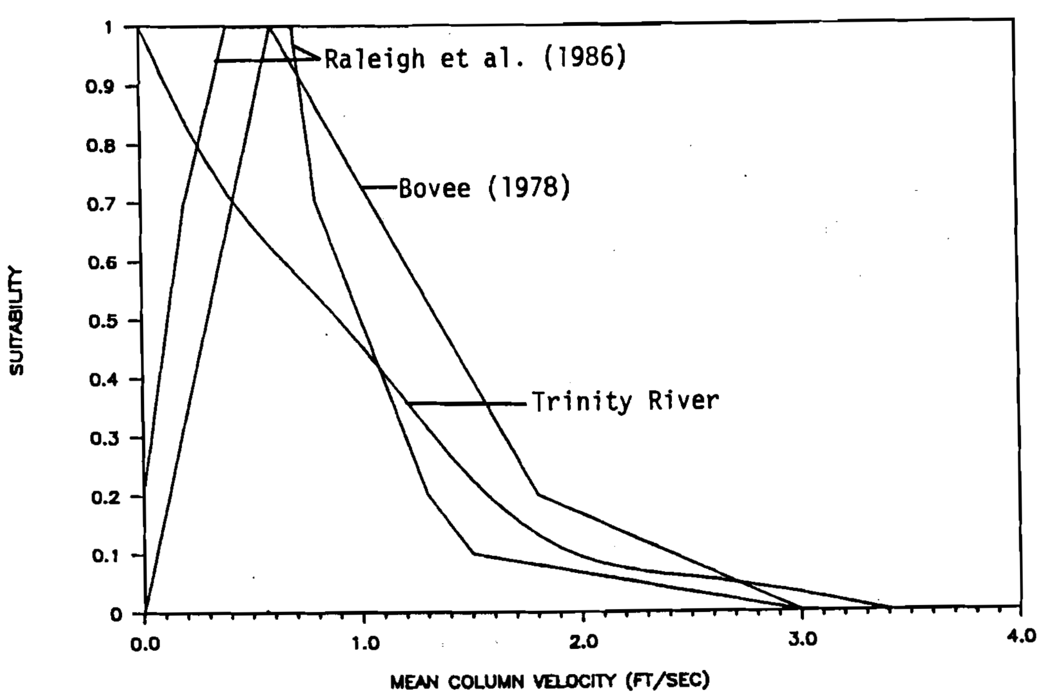


Figure 29. A comparison of preference criteria developed in the upper Trinity River with category I criteria developed by Bovee (1978) and Raleigh et al. (1986) for chinook salmon juveniles.

salmon congregated into slow velocity habitats in close proximity to river substrates or cover items.

Coho salmon fry emerged from February to May and were found to use the same habitats as fry chinook salmon along the stream margins. Juvenile coho salmon did not shift their habitat selection to areas of faster water as did juvenile chinook salmon, rather they tended to seek out slow water habitats that were present in backwaters, sidechannels and stream margins adjacent to large slow runs or pools. Fry and juvenile coho salmon showed a strong preference for slow water velocities. Fry coho salmon preferred depths from 0.9 to 1.2 feet, while juvenile coho salmon preferred depths from 2.3 to 2.5 feet. Category I criteria developed for fry coho salmon by Bovee (1978) present mean column velocities of 0.5 feet per second in water from 1.7 to 2.0 feet deep as optimum (Figure 30). Cover seemed to play a more important role in habitat selection for both fry and juvenile coho salmon. The habitats that were selected usually contained areas of quality cover types, such as brush or logs, over hanging vegetation or thick clusters of aquatic vegetation.

Lister and Genoe (1970) noted that both chinook and coho salmon juveniles on the Big Qualicum River occupied habitat of progressively higher velocities as they grew and spatial segregation apparently resulted from size differences caused by differences in emergence timing, size of emergent fry, and growth rate. In the Sixes River, Stein et al. (1972) found that chinook and coho salmon emerged at similar times, utilized similar habitats and interacted. Microhabitat segregation based on size difference did not occur. They also found that the distributions of the two species changed as temperatures in the main river increased, and speculated, that as temperatures increased, coho salmon left the main river in search of cooler water in the tributaries or died. On the Trinity River, fry and juvenile chinook salmon greatly outnumbered fry and juvenile coho salmon during the study period. As fry, both species were found to interact often and were commonly found together in one school. Antagonistic behavior between the two species was rarely observed, and it appeared that as each species grew their differences in habitat selection provided for spatial segregation between the two species. It is also possible that coho salmon are less tolerant of crowded conditions caused by high densities of chinook salmon, and therefore, sought out habitat types that were less utilized by juvenile chinook salmon.

The low numbers of adult steelhead trout that entered the Trinity River on their spawning migration in 1985 and 1986 greatly hindered our ability to gather fry steelhead use data in the subsequent years. There was never any problem in obtaining use data on juvenile steelhead during the study period, probably because many of these larger juveniles reared in tributary streams as fry. Steelhead trout fry were usually found along stream margins adjacent to runs and

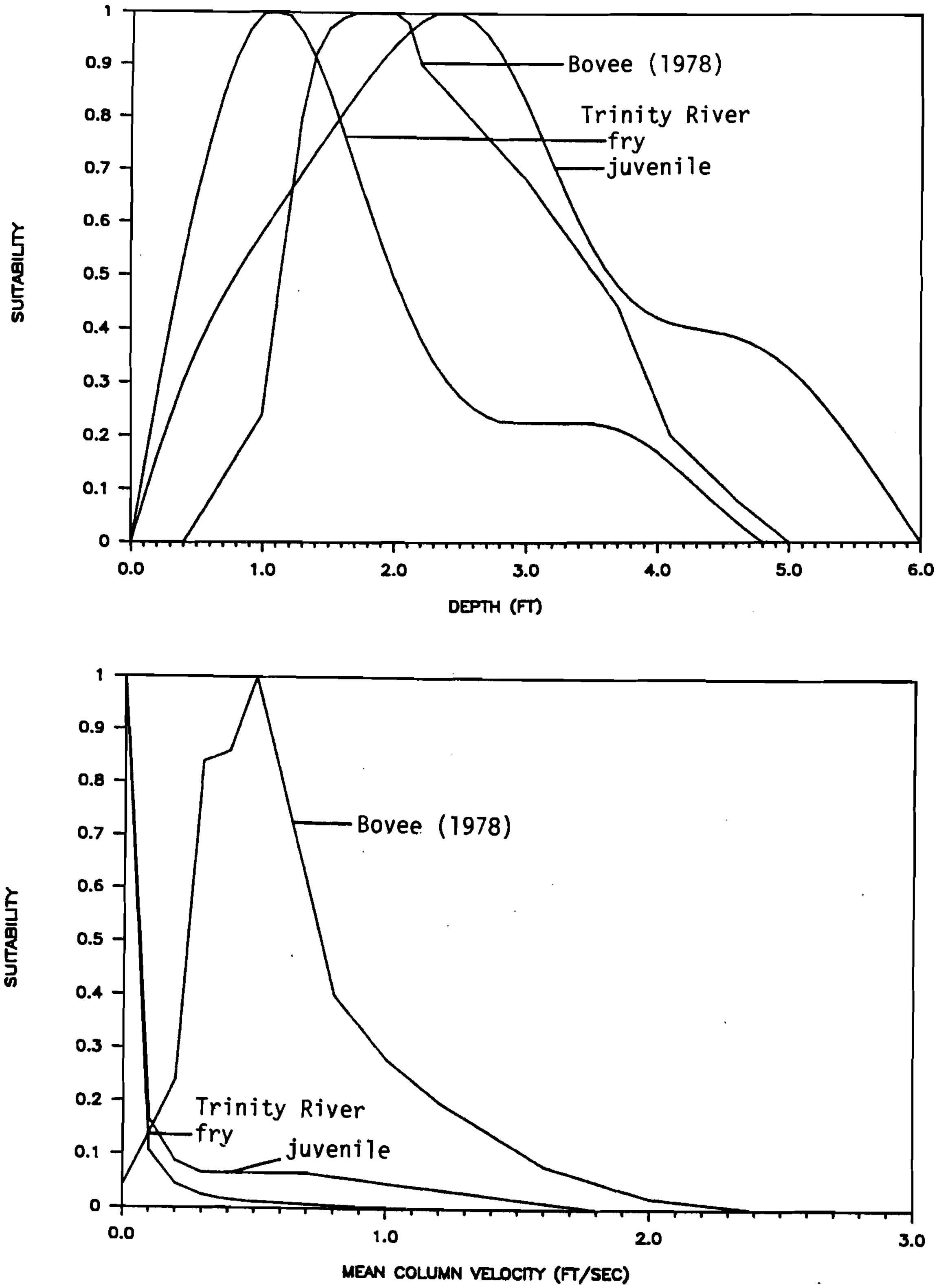


Figure 30. A comparison of preference criteria developed in the upper Trinity River for coho salmon fry and juveniles with category I criteria developed by Bovee (1978) for coho salmon fry.

riffles or along the edges of transition habitats between riffles and pools. Fry assumed focal points on or very near the stream bottom between cobbles or within woody debris. Juvenile salmon were frequently observed in the water column above fry steelhead trout in the same microhabitats. Unlike fry chinook or coho salmon, fry steelhead were often found in turbulent water present in shallow riffles. Their association with velocity shelters on or near the stream bottom allowed them to use these more turbulent microhabitats. Fry steelhead were rarely observed in monotypic habitats present in long slow runs or pools.

Juvenile steelhead trout preferred run, riffle, and riffle-pool transition habitats that provided a high degree of velocity diversity. Preferred depths from 2.0 feet and greater with mean column velocities from 1.0 to 1.3 feet per second. Juvenile steelhead actively defended feeding stations in riffles and across the tail end of run habitats. Object cover, boulders, large cobbles or woody debris, played an important role by providing velocity shelters where juvenile steelhead could establish feeding stations with little effort. When found in riffle-pool transition habitats groups of juvenile steelhead were often seen feeding in the same locations without displaying any aggressive behavior among themselves. In these microhabitats steelhead were usually positioned underneath areas of high surface water velocity along the ledge located at the upper boundary of the pool. In these locations juvenile steelhead could maintain focal points in near zero velocity water and still take advantage of drift organisms originating in the riffle upstream. Cover objects were seldom present in these riffle-pool transition habitats, however, surface turbulence did provide concealment from surface predators.

Shear velocity zones, areas of rapid velocity change, proved to be a critical hydraulic characteristic present in the microhabitats selected by juvenile chinook salmon and steelhead trout. These shear zones provided opportunistic feeding stations for juvenile salmon and trout where focal points could be established in slow velocity areas and yet still be in close proximity to higher velocity areas where food, available in the form of drift, is more easily accessible and more abundant. Net energy gain in these microhabitats is probably optimized because less energy is used to maintain focal points and distances traveled to capture prey items are reduced. Lisle (1981) describes the importance of large roughness elements (boulders and woody debris) as a key resource to fish habitat by providing a diversity of channel form and substrate conditions. These same roughness elements also provide important rearing habitat for anadromous salmonids by increasing velocity diversity through the formation of shear velocity zones. Habitat suitability criteria based on focal point velocities, either taken as mean column water velocities or as fish nose velocities, fail to measure the presence of these shear velocity zones that are located adjacent to focal points and, therefore, may misrepresent actual fish habitat preferences for rearing salmonids. A form of preference criteria that considers both focal point velocities and adjacent cell velocities would be a better measure of fish preference in these instances.

Future habitat suitability studies can alleviate this problem by developing criteria that not only describe focal point velocities, but also quantify the distances traveled by the target species to capture prey items as well describing the velocities that are present at the location where prey items are captured. Quantification of these two additional parameters may then be input into the HABTAV program of the IFIM to predict a more accurate weighted useable area versus discharge relationship for those species and lifestages that utilize shear velocity zones.

The concept that preference criteria, by eliminating habitat bias, may be transferred to other streams or rivers is questionable. Development of preference criteria is dependent on the available habitat present within the area of study. Therefore, if a habitat type is not present within the study area the influence of that habitat type on the target species habitat selection will not be represented in the resulting preference criteria. Based on this fact, it is important that other researchers validate that the available habitat in the system where the preference criteria are being considered for use is similar to the available habitat present in the system where the preference criteria were developed. Only after the available habitats of the two systems have been found to be similar should preference criteria be transferred.

Appendix E presents habitat preference criteria judged at this time to be best suited for habitat studies in the Trinity River. The limitaions of these criteria should be clearly understood before they are utilized in other streams or rivers for similiar type studies.

REFERENCES

Aceituno, M.E., and M. Hampton. Validation of habitat availability determinations by comparing field observations with hydraulic model (IFG-4) output. pp. 322-334 in K. Bovee and J.R. Zuboy, eds. Proceedings of a workshop on the development and evaluation of habitat criteria. U.S. Fish Wildl. Serv. Biol. Rep. 88(11). 407 pp.

Bovee, K.D. 1978. Probability of use criteria for the family salmonidae. Instream Flow Information Paper No. 4. U.S. Fish Wildl. Serv. FWS/OBS-78/07

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper No. 12. U.S. Fish Wildl. Serv. FWS/OBS-82/26

Bovee, K.D. 1986. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Instream Flow Information Paper No. 21. U.S. Fish Wildl. Serv. Biol. Rep. 86(7). 235 pp.

Bovee, K.D., and T. Cochnauer. 1977. Development and evaluation of wieghted criteria, probability - of - use curves for instream flow assessments: fisheries. Instream Flow Information Paper No. 3. U.S. Fish Wildl. Serv. FWS/OBS-77/63

Brusven, M.A. 1977. Effects of sediments on insects. Page 43 in D.L. Kibbee (ed.). Transport of granitic sediments in streams and its effects on insects and fish. USDA Forest Sevice. Forest, Wildl., and Range Exp. Sta. Bull. 17. Univ. Idaho, Moscow, ID.

Cheslak, E., and J. Garcia. 1987. Sensitivity of PHABSIM model output to methods for fitting functions of curves to species preference data. in K.D. Bovee, and J. Zuboy, eds. Proceedings of a workshop on the development and evaluation of habitat criteria for fish. U.S. Fish Wildl. Serv. Biol. Rep. (in press)

Cheslak, E., EA Engineering, Science, and Technology, Inc. February 2, 1988. Personal Communication.

Hubbel, P.M. 1973. A program to identify and correct salmon and steelhead problems in the Trinity River Basin. Calif. Dept. of Fish and Game. Report to the Trinity River Basin Fish & Wildlife Task Force, Sacramento, Calif. 70 pp.

Kurko, K.W. 1977. Investigations on the amount of potential spawning area available to chinook, pink, and chum salmon in the upper Skagit River, Washington. M.S. Thesis. University of Washington, Seattle. 76 pp.

Leidy, R.A., and G.R. Leidy. 1984. Life stage priodicities of anadromous salmonids in the Klamath River Basin, Northwestern California. U.S. Fish Wildl. Serv., Division of Ecological Services, Sacramento, California. 21 pp.

Lisle, T.E. 1981. Roughness elements: a key resource to improve anadromous fish habitat. in T.J. Hassler ed. Proceedings: propagation, enhancement, and rehabilitation of anadromous salmonid populations and habitat symposium. October 15-17, 1981, Humboldt State University, Arcata, California.

Lister, D.B., and H.S. Genoe. 1970. Stream habitat utilization by cohabiting underyearlings of chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmonids. J. Fish. Res. Board Can. 27:1215-1224.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's guide to the Physical Habitat Simulation System. Instream Flow Information Paper 11. U.S. Fish Wildl. Serv. FWS/OBS-81/43 Revised. 475pp.

Mills, T. J., Cailfornia Department of Fish and Game. February 3, 1988. Personal Communication.

Moffett, J.W., and S.H. Smith. 1950. Biological investigations of the fishery resources of Trinity River, Calif. U.S. Fish Wildl. Serv. Special Scientific Report - Fisheries No. 12 71 pp.

Raleigh, R.F., W.J. Miller, and P.C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: chinook salmon. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.122) 64 pp.

Reimers, P.E. 1968. Social behavior among juvenile fall chinook salmon. J. Fish. Res. Bd. Canada, 25(9):2005-2008

Sams, R.E., and L.S. Pearson. 1963. Methods for determining spawning flows for anadromous salmonids. Oregon Fish Commission Draft Report. 68 pp.

Stein, R.A., P.E. Reimers, and J.D. Hall. 1972. Social interaction between juvenile coho (Oncorhynchus kisutch) and fall chinook salmon (O. tshawytscha) in Sixes River, Oregon. J. Fish. Res. Bd. Canada 29:1737-1748

Smith, A.K. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Amer. Fish. Soc., 102(2):312-316

Stempel, J.M. 1984. Development of fish preference curves for spring chinook and rainbow trout in the Yakima River Basin. U.S. Fish Wildl. Serv., Ecological Sevices, Moses Lake, WA. 20 pp.

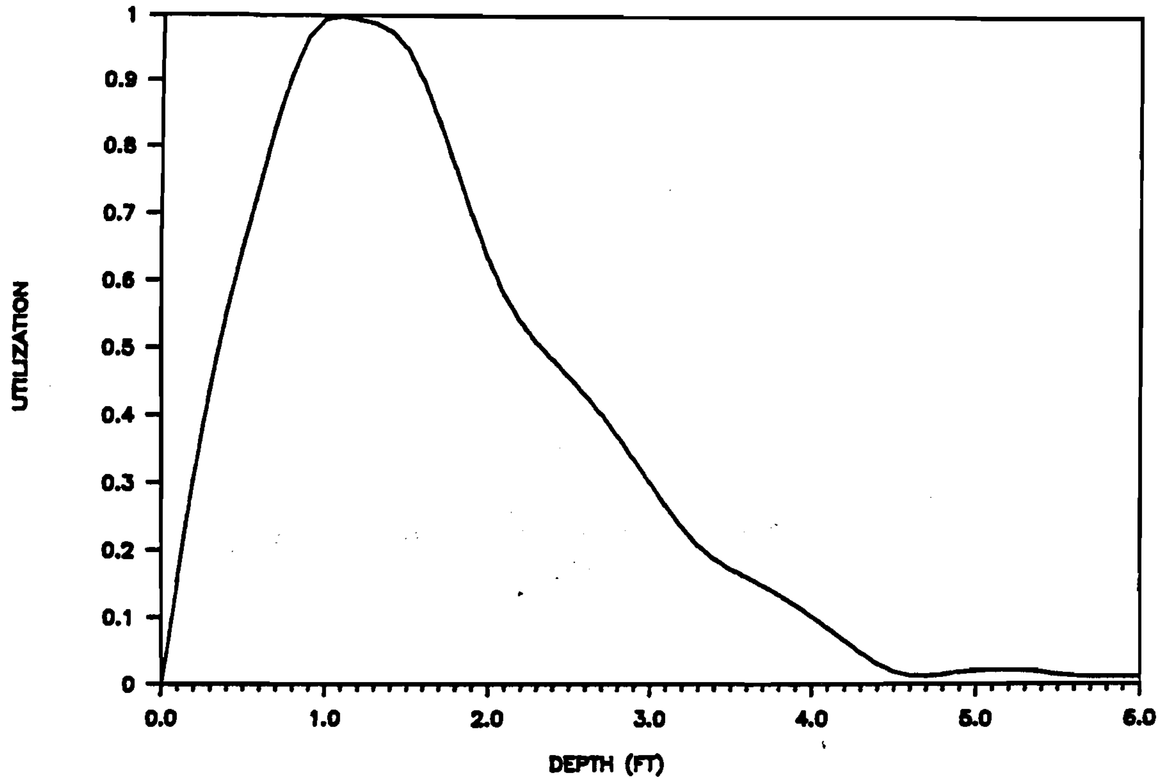
U.S. Fish & Wildlife Service. 1985. Life history information on juvenile chinook salmon in the lower American River. Report to the Bureau of Reclamation, American River Studies. U.S. Fish Wildl. Serv., Division of Ecological Services, Sacramento, CA.

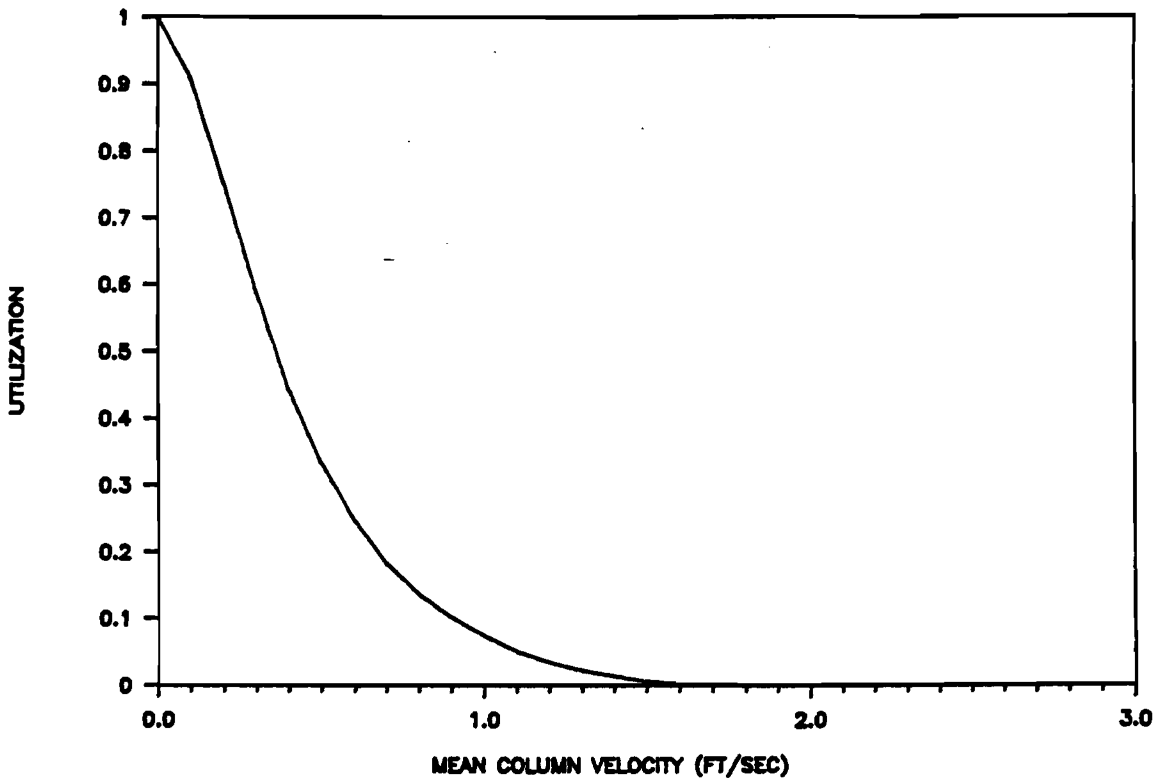
Vincent-Lang, D., A. Hoffman, A. Bingham, and C. Estes. 1984. Habitat suitability criteria for chinook, coho, and pink salmon spawning in tributaries of the middle Susitna River. Chapter 9 in C.C. Estes, and D.S. Vincent-Lang, eds. Aquatic habitat and instream flow investigations (May-October 1983). Alaska Dept. Fish Game Susitna Hydro Aquatic Studies Report No. 3, Anchorage.

Vogel, D.A. 1982. Preferred spawning velocities, depths, and substrates for fall chinook salmon in Battle Creek, California. USDI Fish Wildl. Serv., Fisheries Assistance Office, Red Bluff, CA. 8 pp.

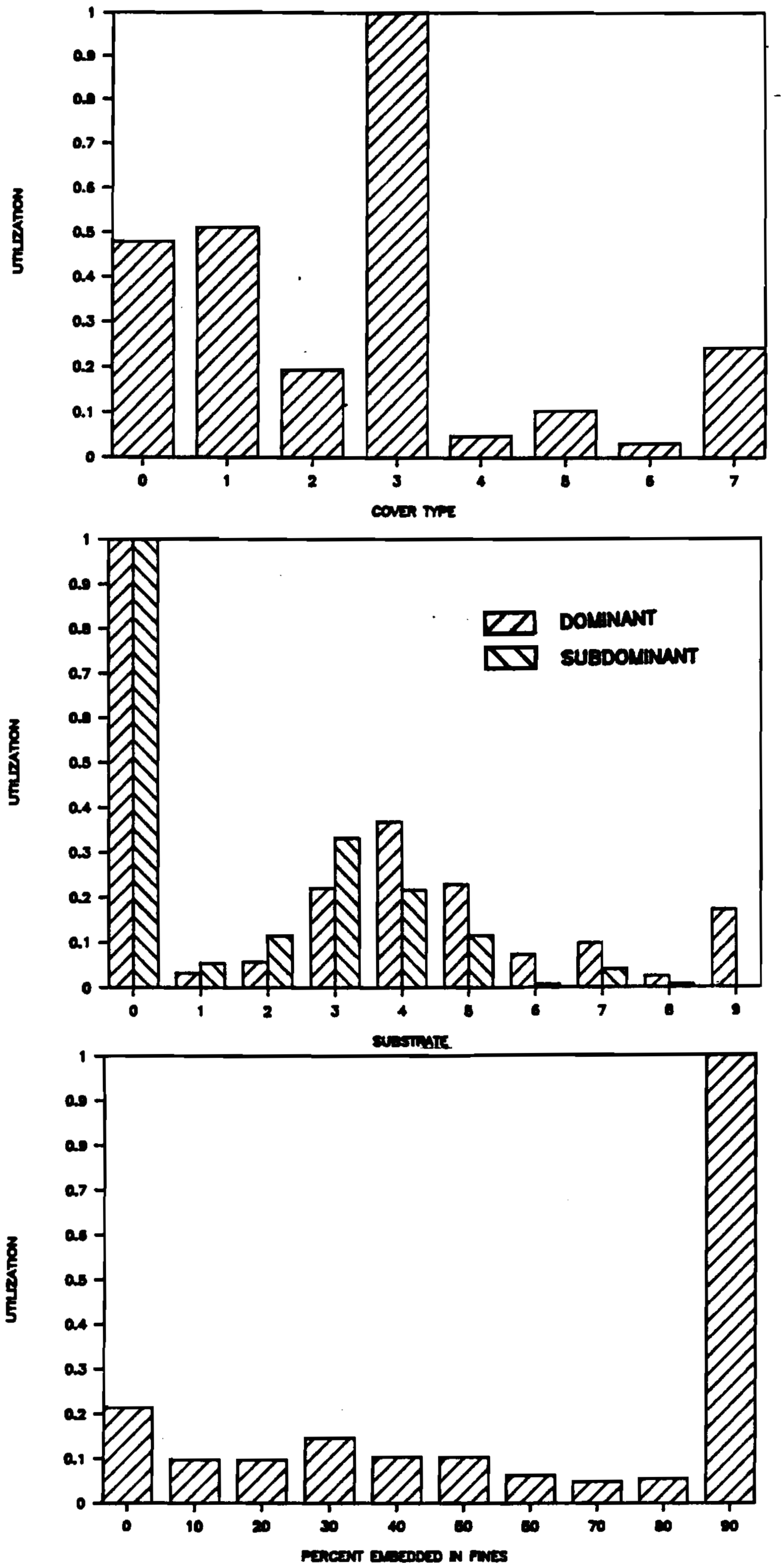
APPENDIX A

HABITAT UTILIZATION CRITERIA FOR FRY, JUVENILE, AND SPAWNING LIFESTAGES OF THE ANADROMOUS SALMONIDS OF THE UPPER TRINITY RIVER, CALIFORNIA, 1985-1987.



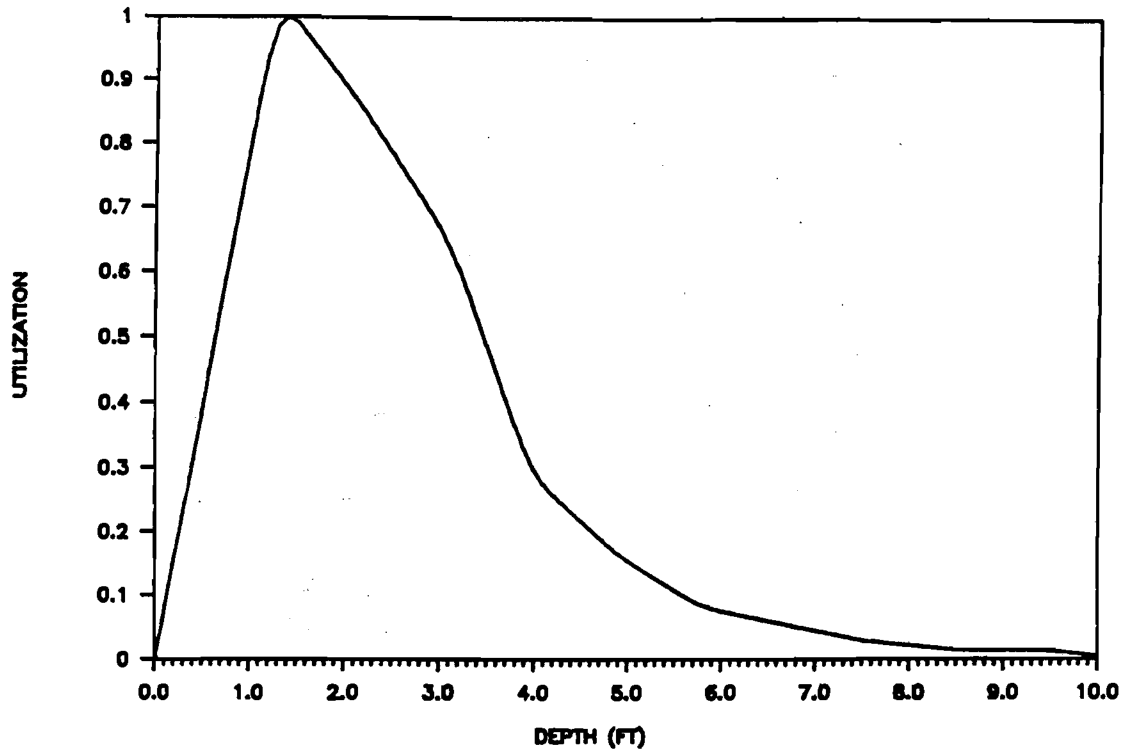


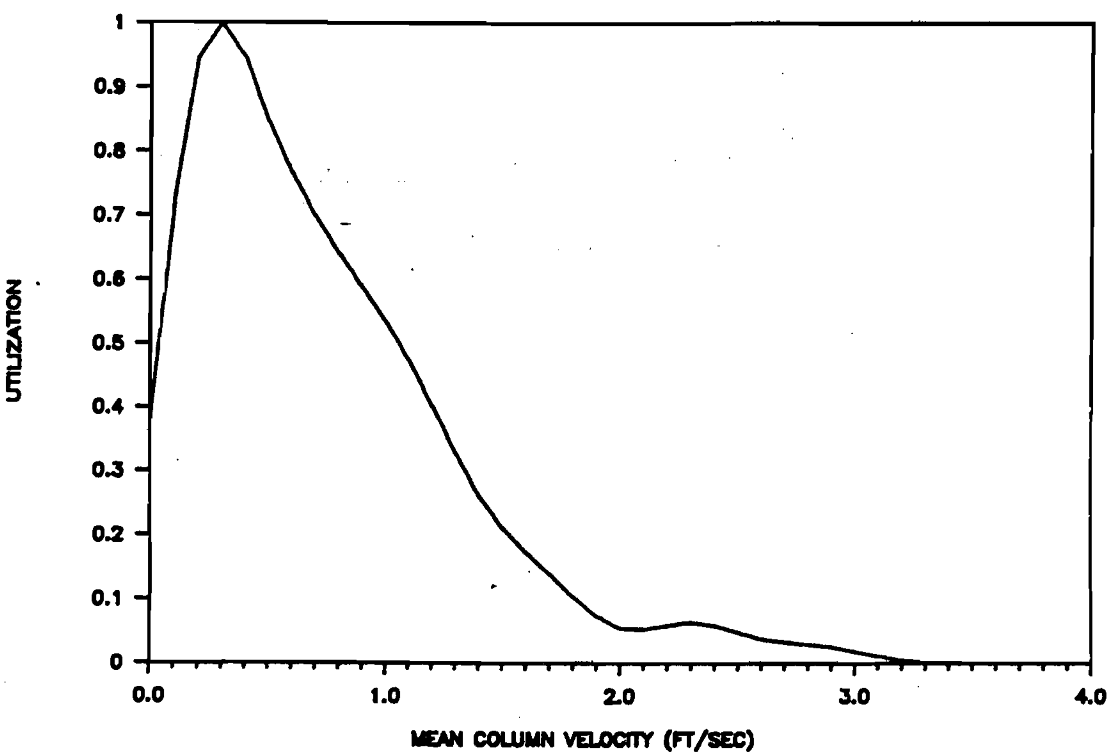
Habitat utilization criteria describing total depths and mean column velocites selcted by chinook salmon fry in the upper Trinity River, CA., 1985-1987.



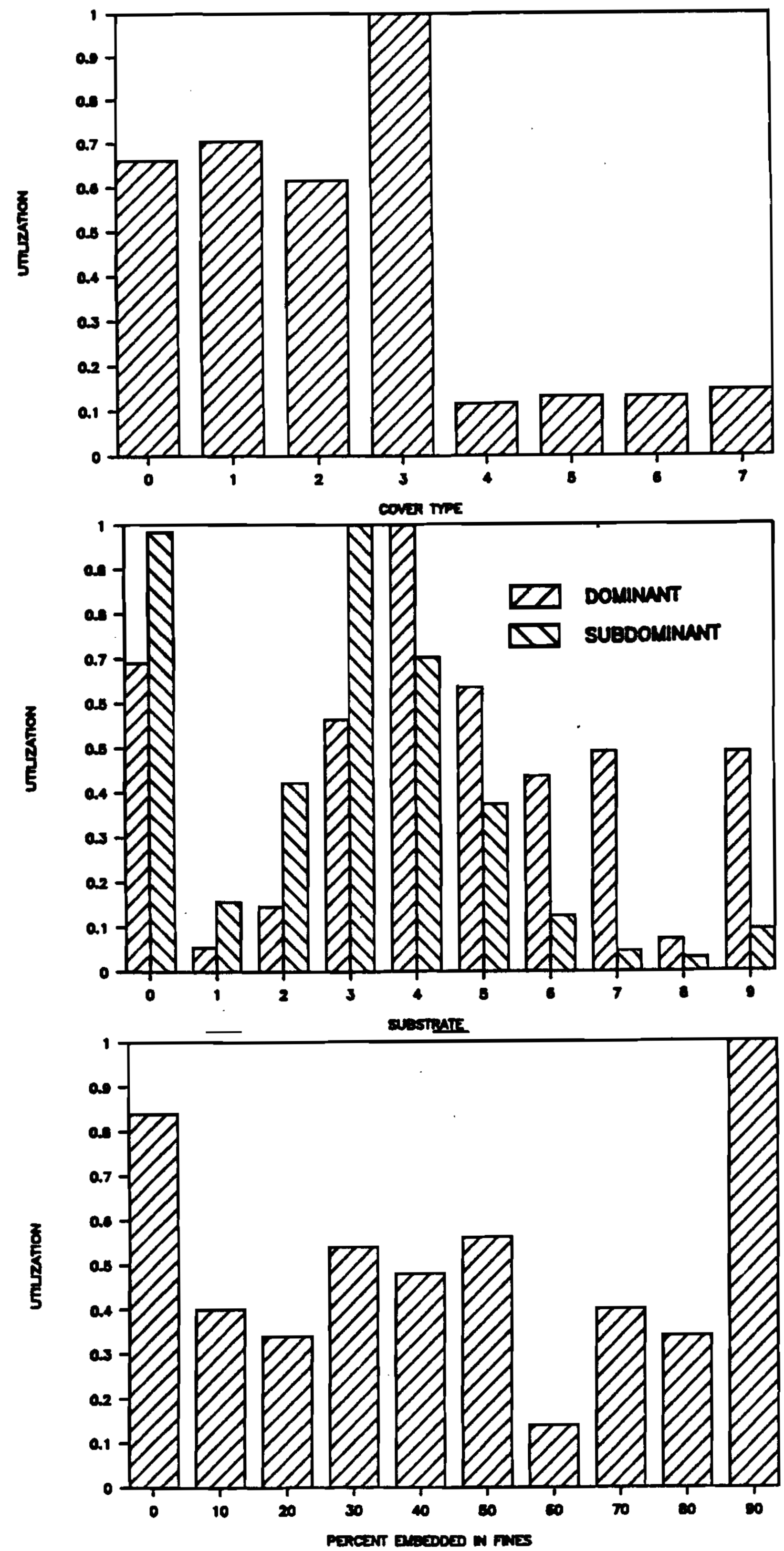
Habitat utilization criteria describing cover and substrates selected by chinook salmon fry in the upper Trinity River, CA., 1985-1987.

APPENDIX A

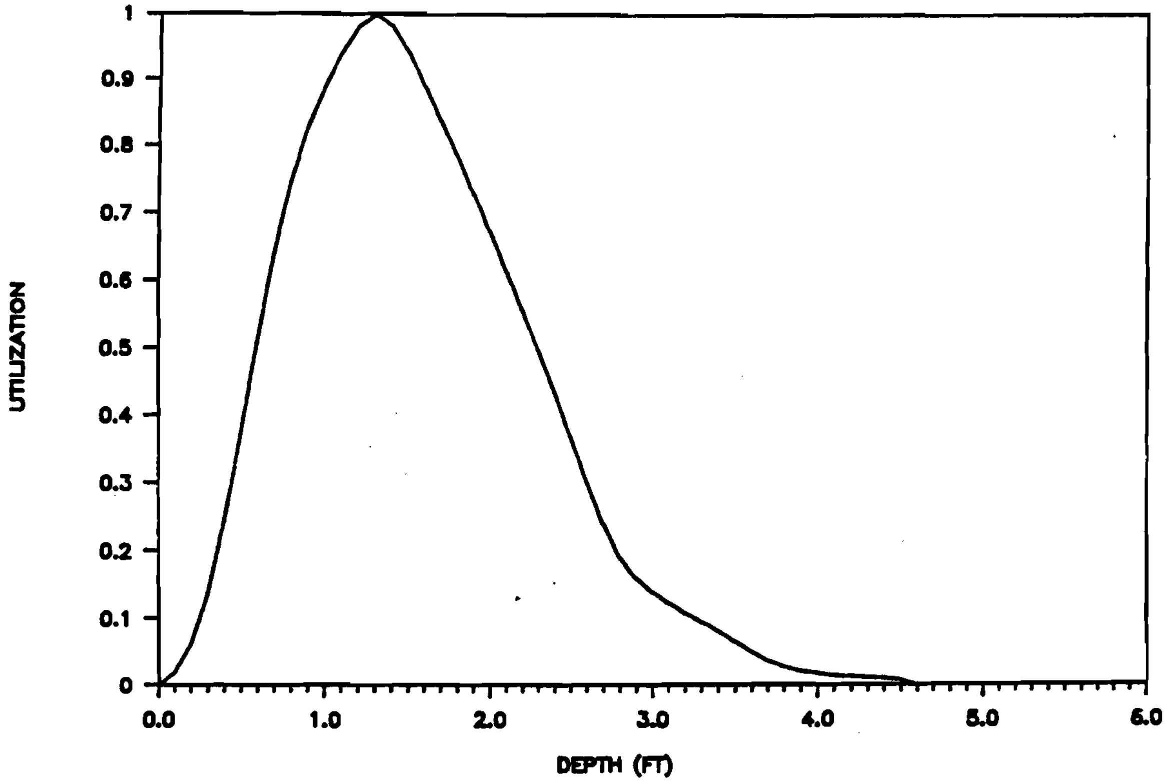


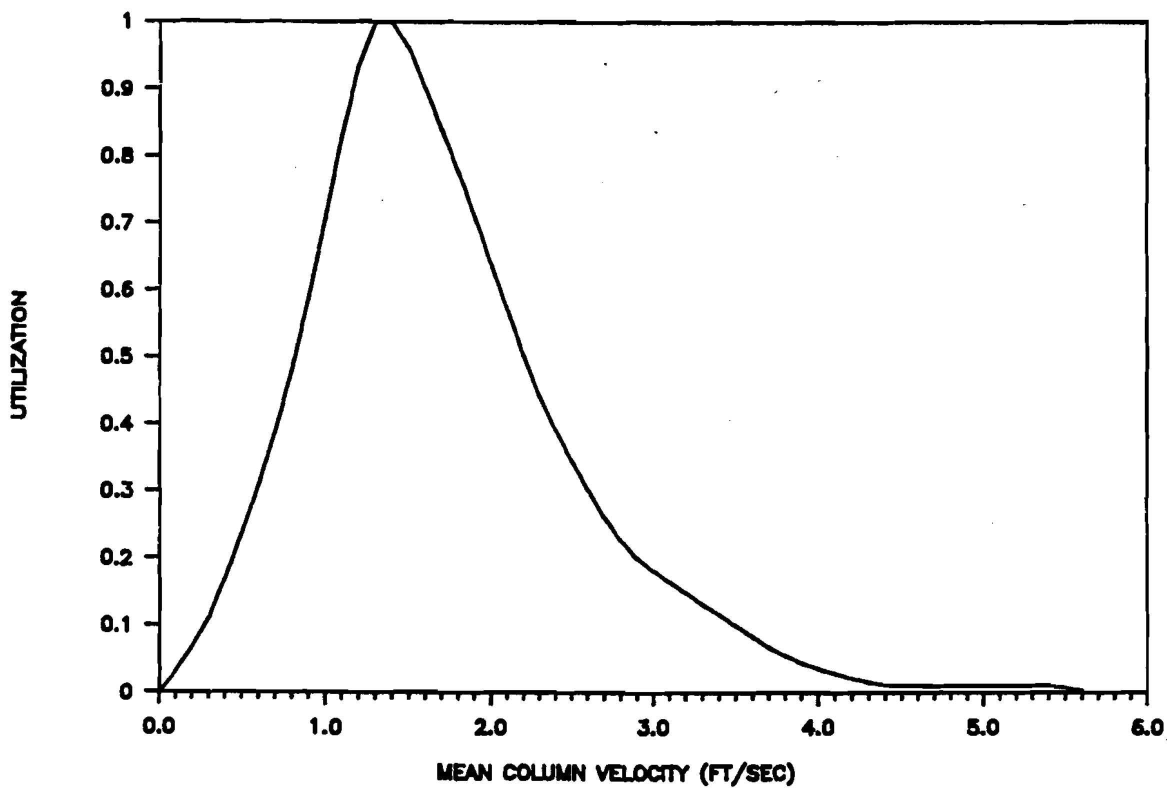


Habitat utilization criteria describing total depths and mean column velocites selcted by chinook salmon juveniles in the upper Trinity River, CA., 1985-1987.

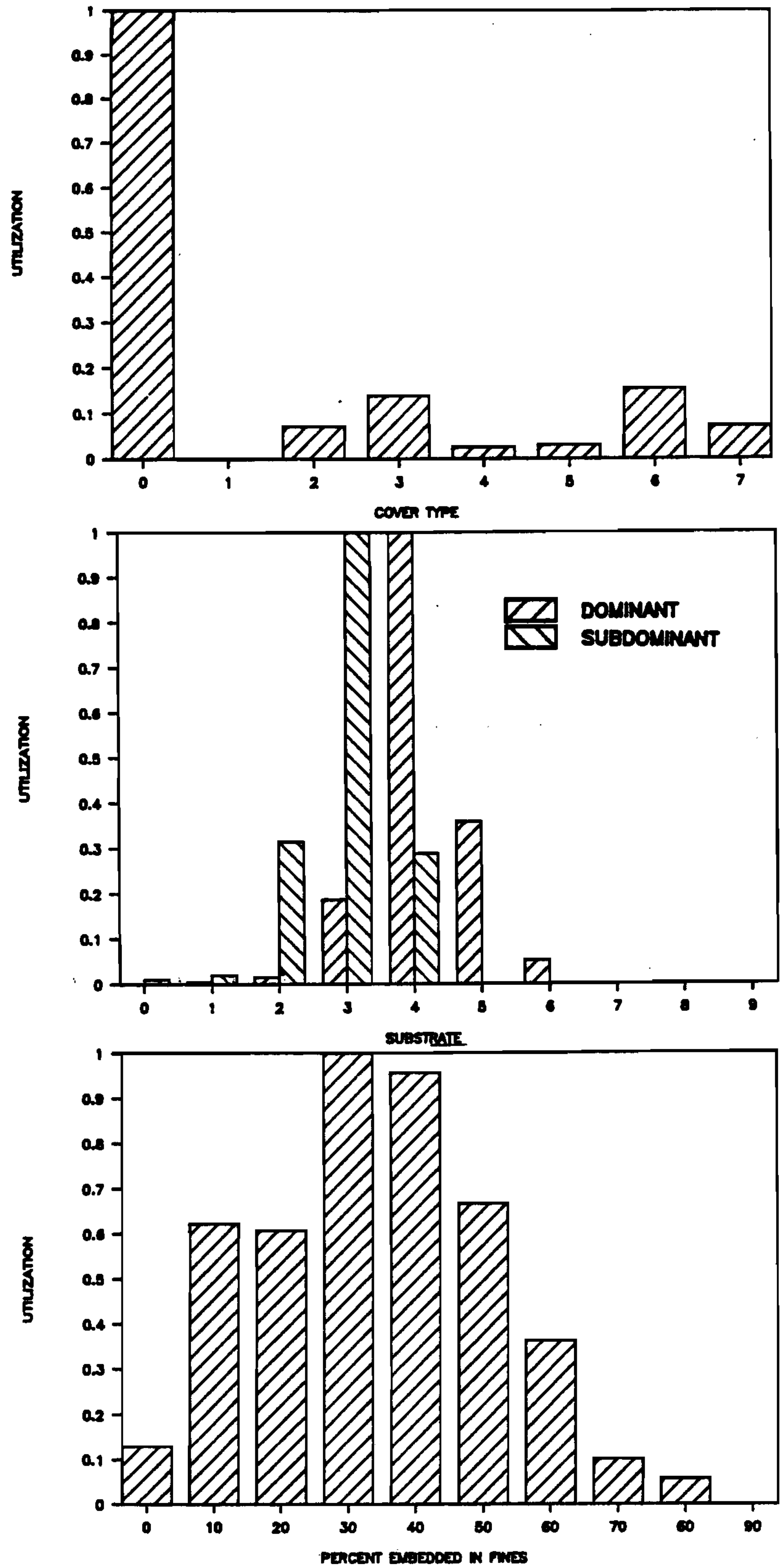


Habitat utilization criteria describing cover and substrates selected by chinook salmon juveniles in the upper Trinity River, CA., 1985-1987.

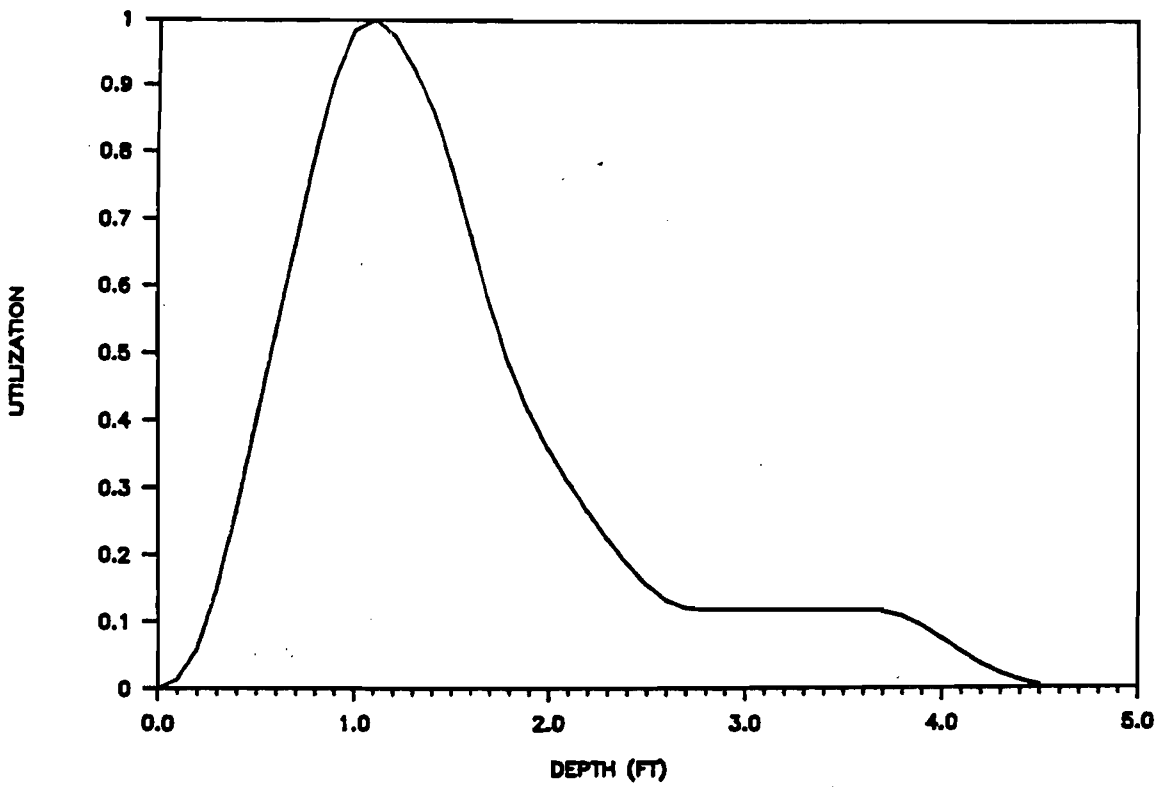


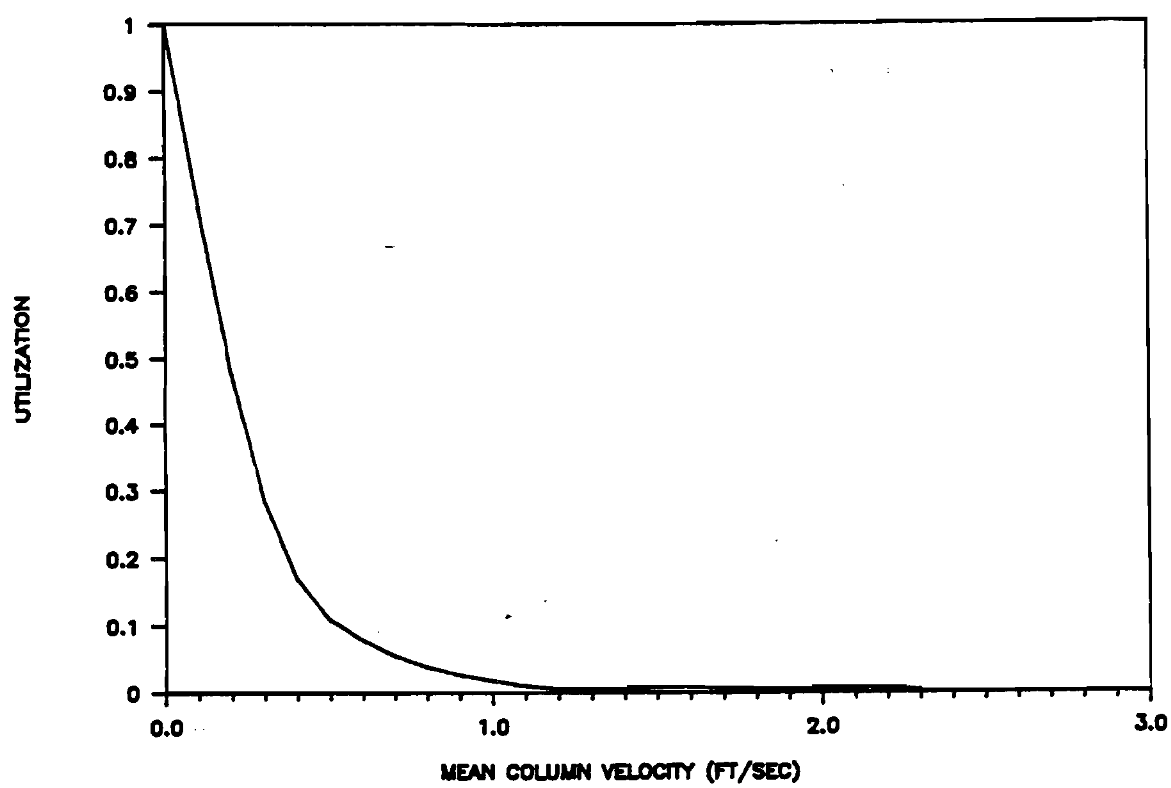


Habitat utilization criteria describing total depths and mean column velocites selcted by spawning chinook salmon in the upper Trinity River, CA., 1985-1987.

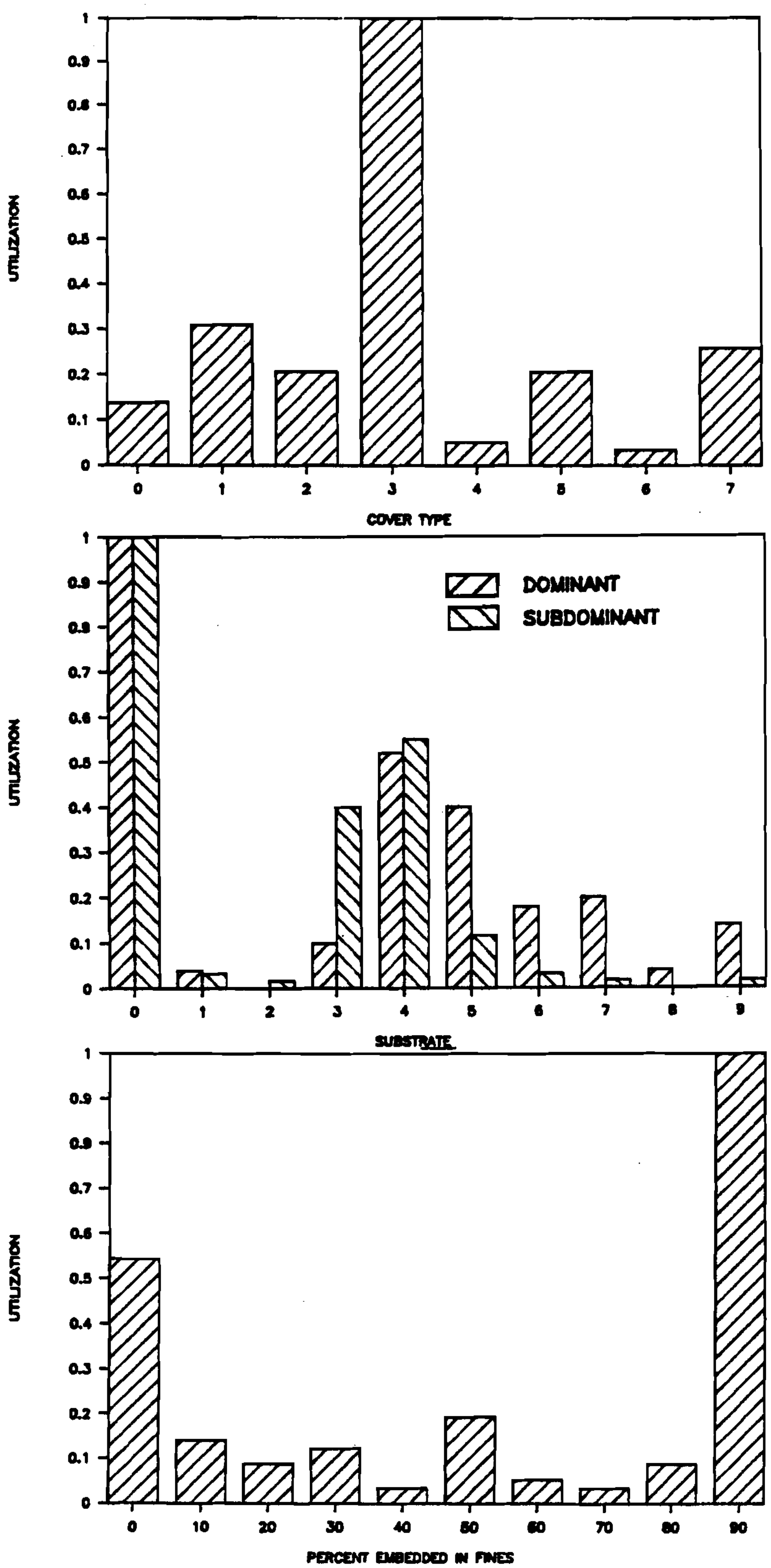


Habitat utilization criteria describing cover and substrates selected by spawning chinook salmon in the upper Trinity River, CA., 1985-1987.

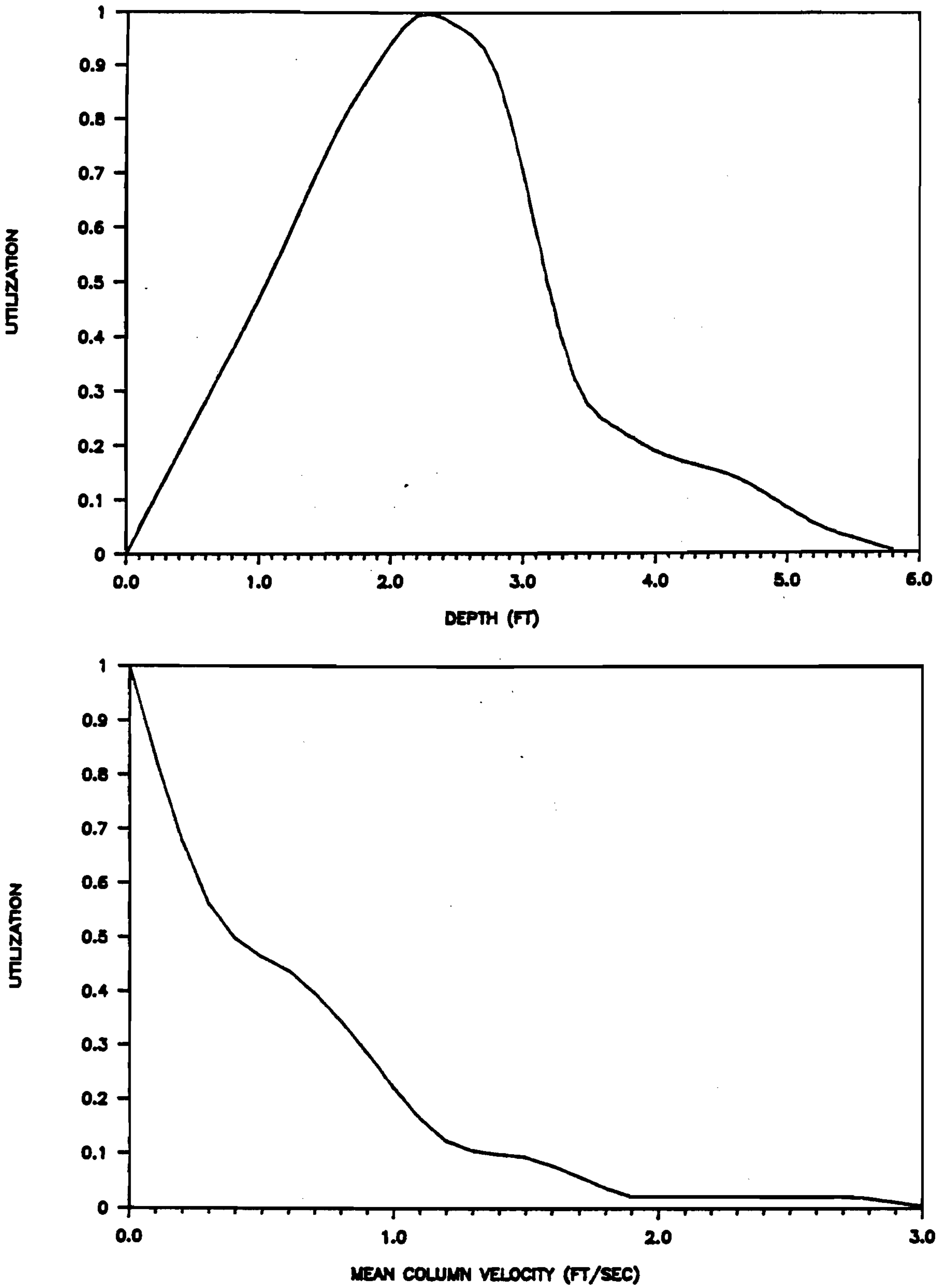




Habitat utilization criteria describing total depths and mean column velocites selcted by coho salmon fry in the upper Trinity River, CA., 1985-1987.



Habitat utilization criteria describing cover and substrates selected by coho salmon fry in the upper Trinity River, CA., 1985-1987.



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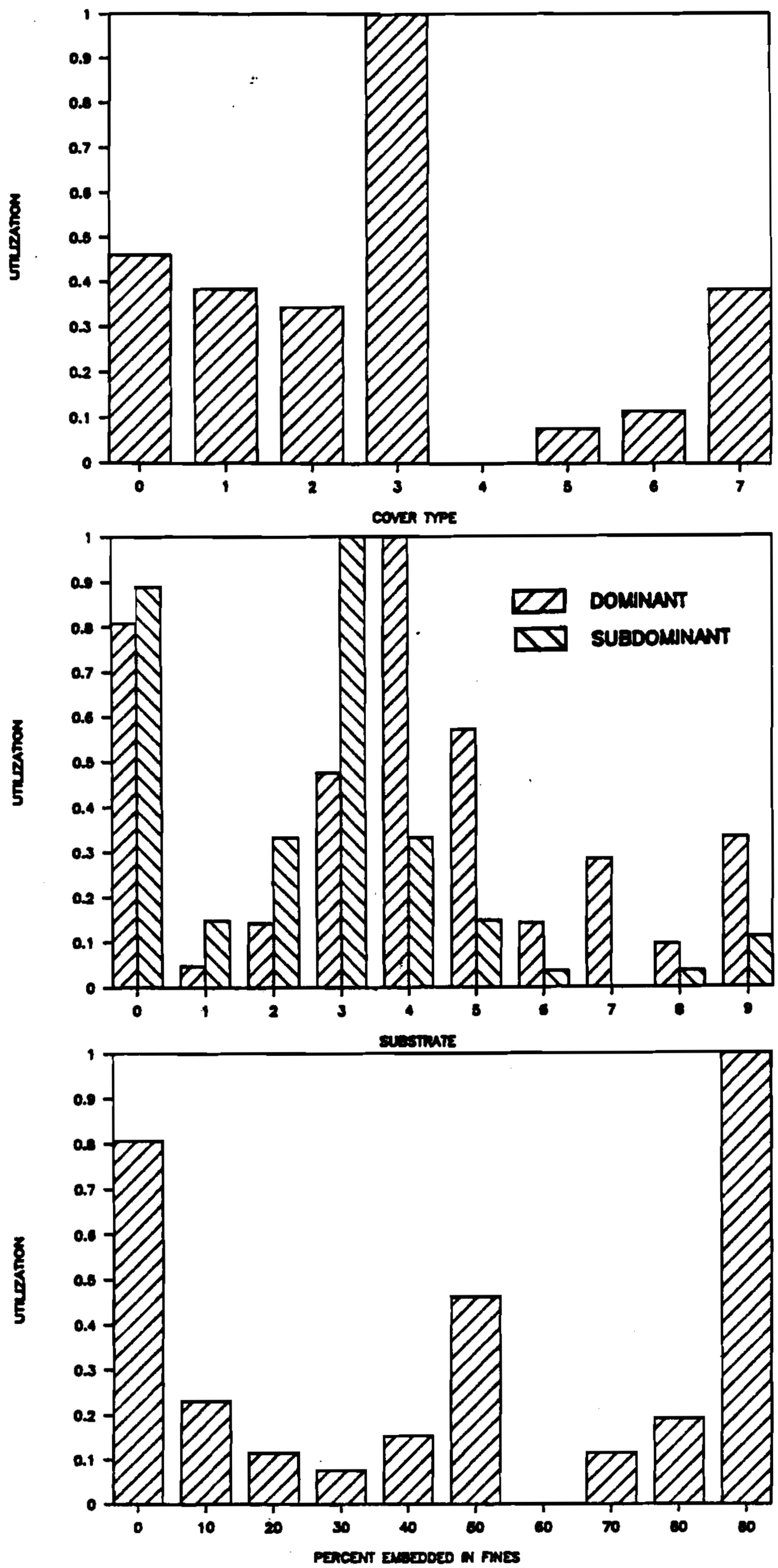
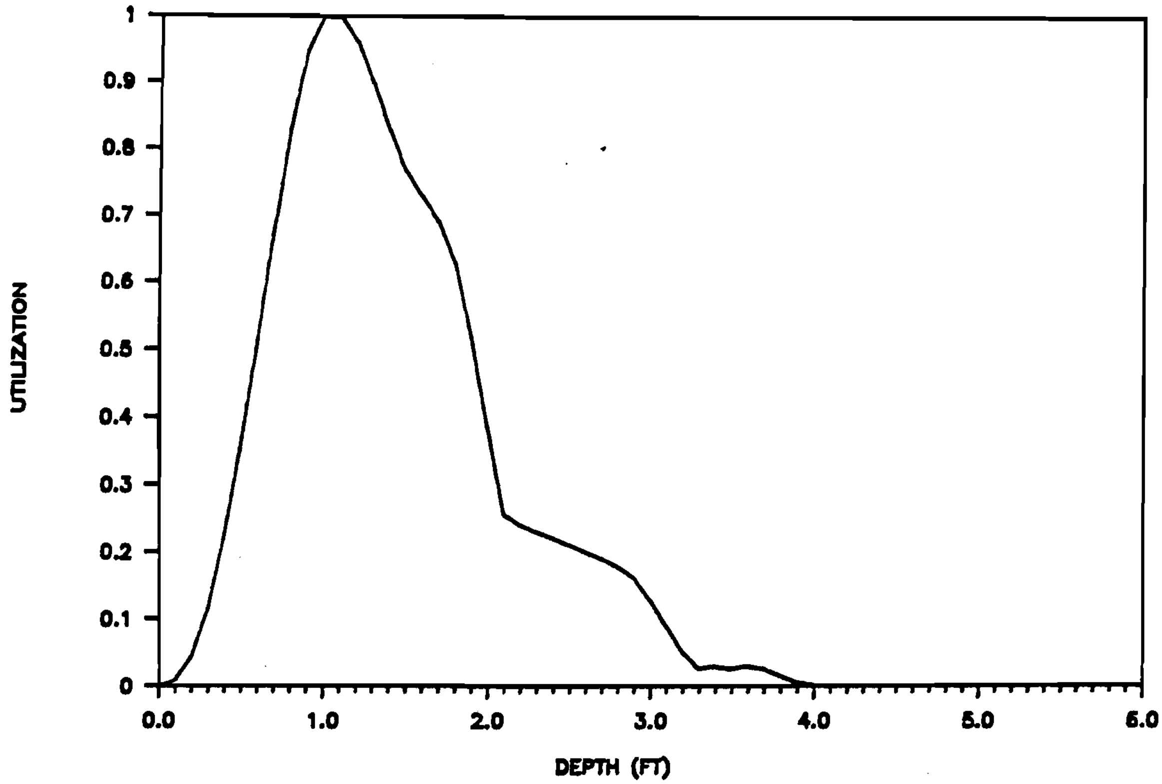
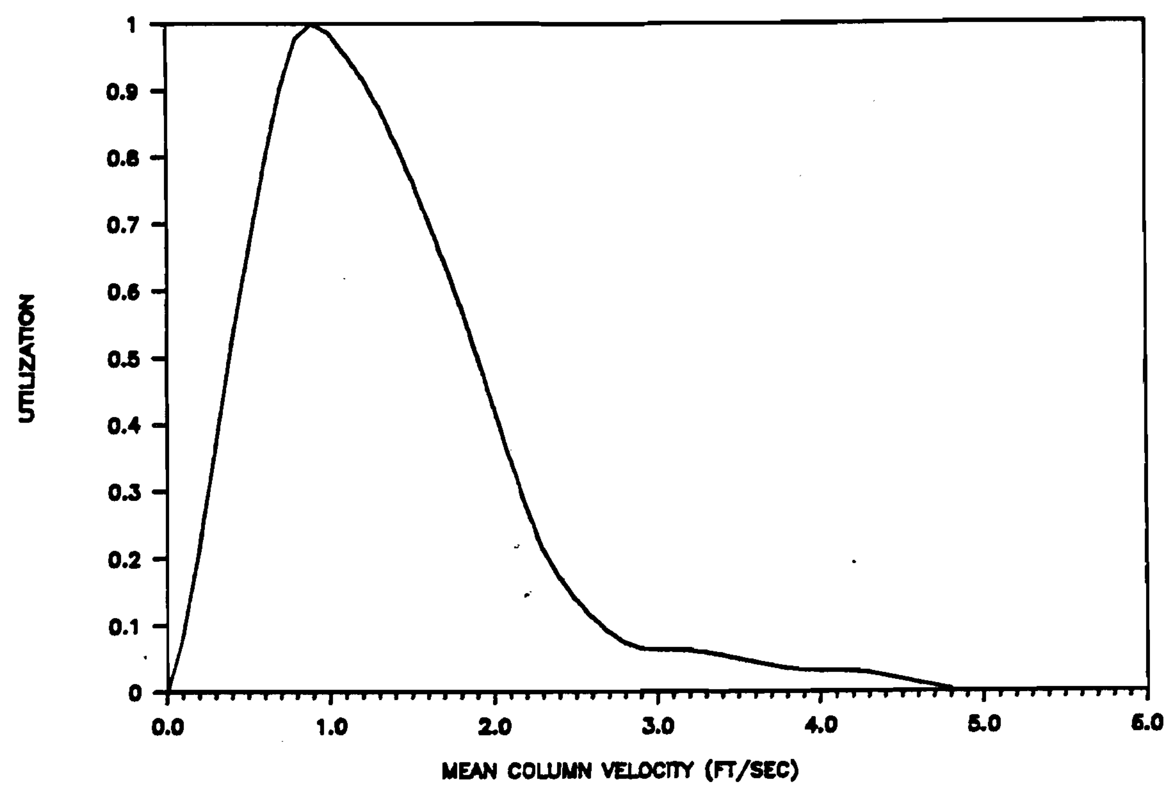
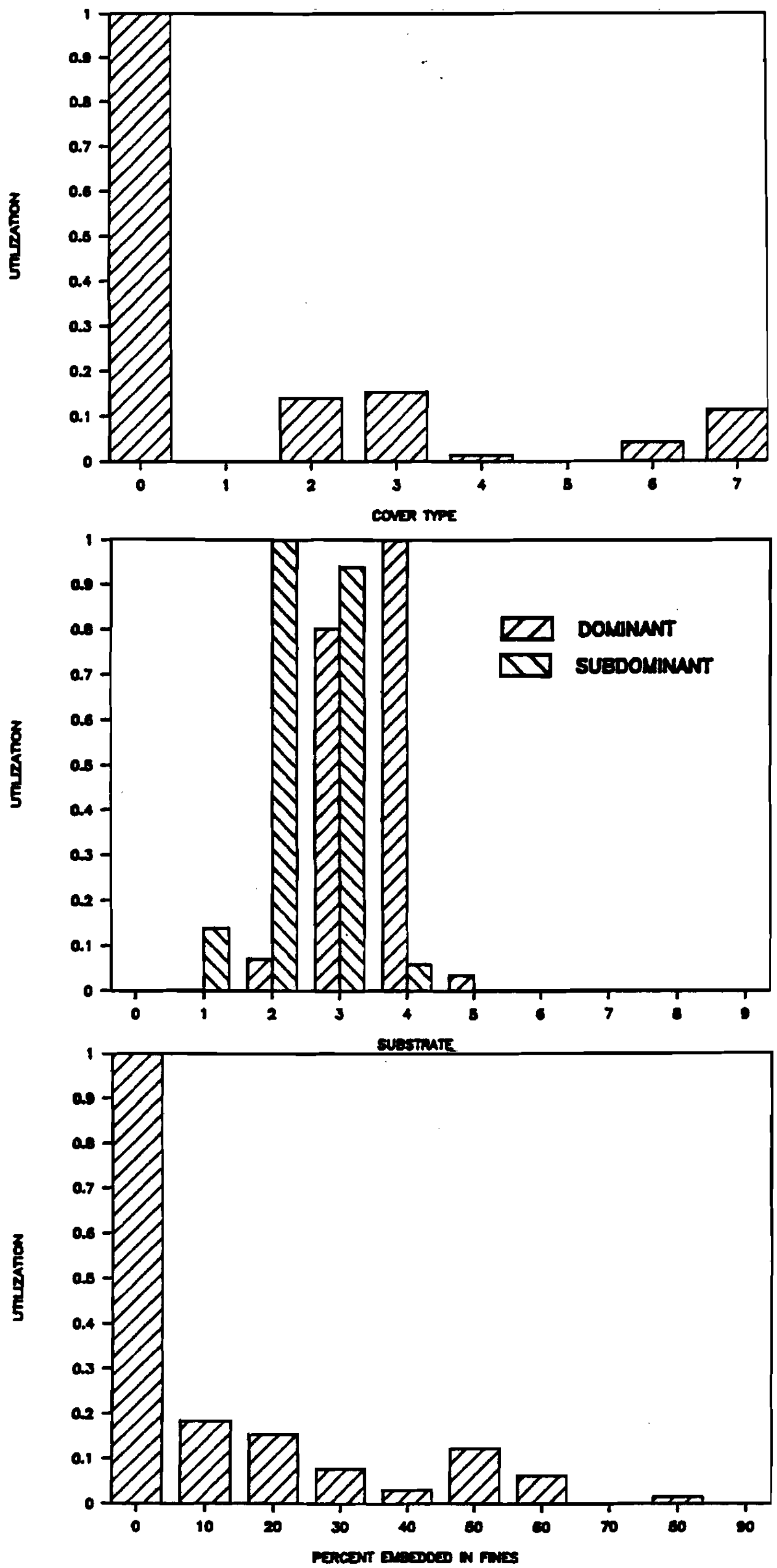


Habitat utilization criteria describing cover and substrates selected by coho salmon juveniles in the upper Trinity River, CA., 1985-1987.





Habitat utilization criteria describing total depths and mean column velocites selcted by spawning coho salmon in the upper Trinity River, CA., 1985-1987.



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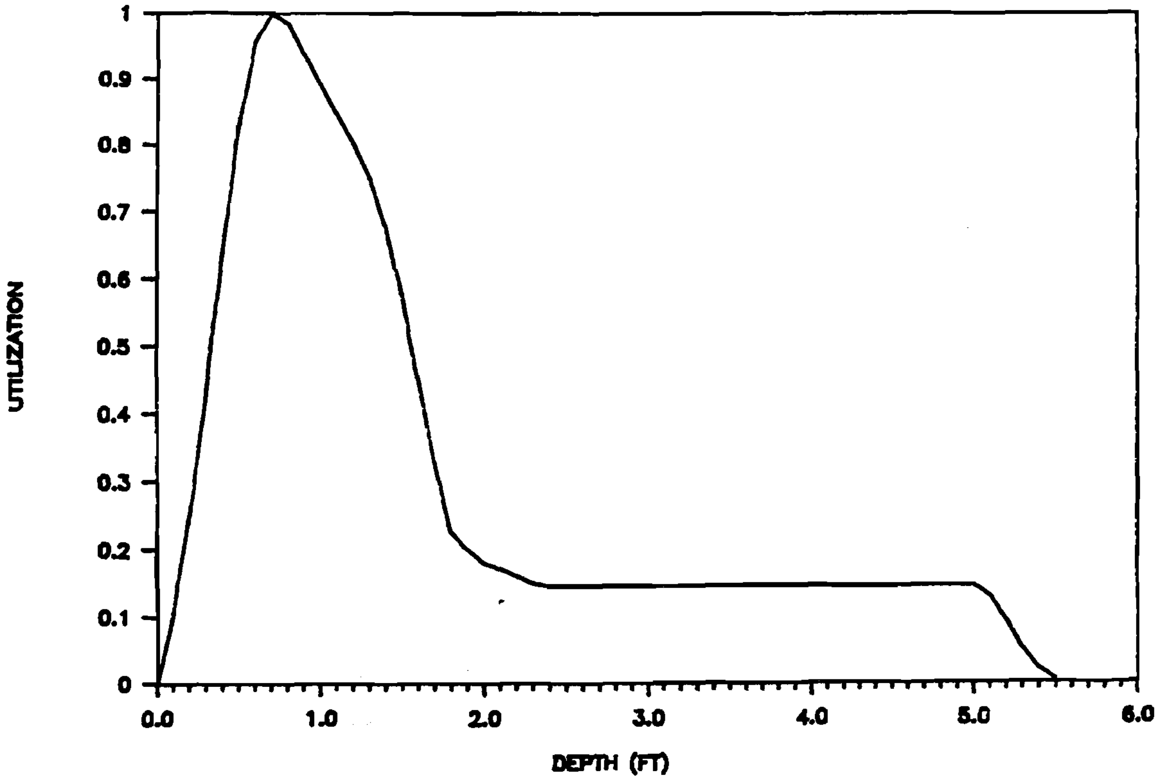
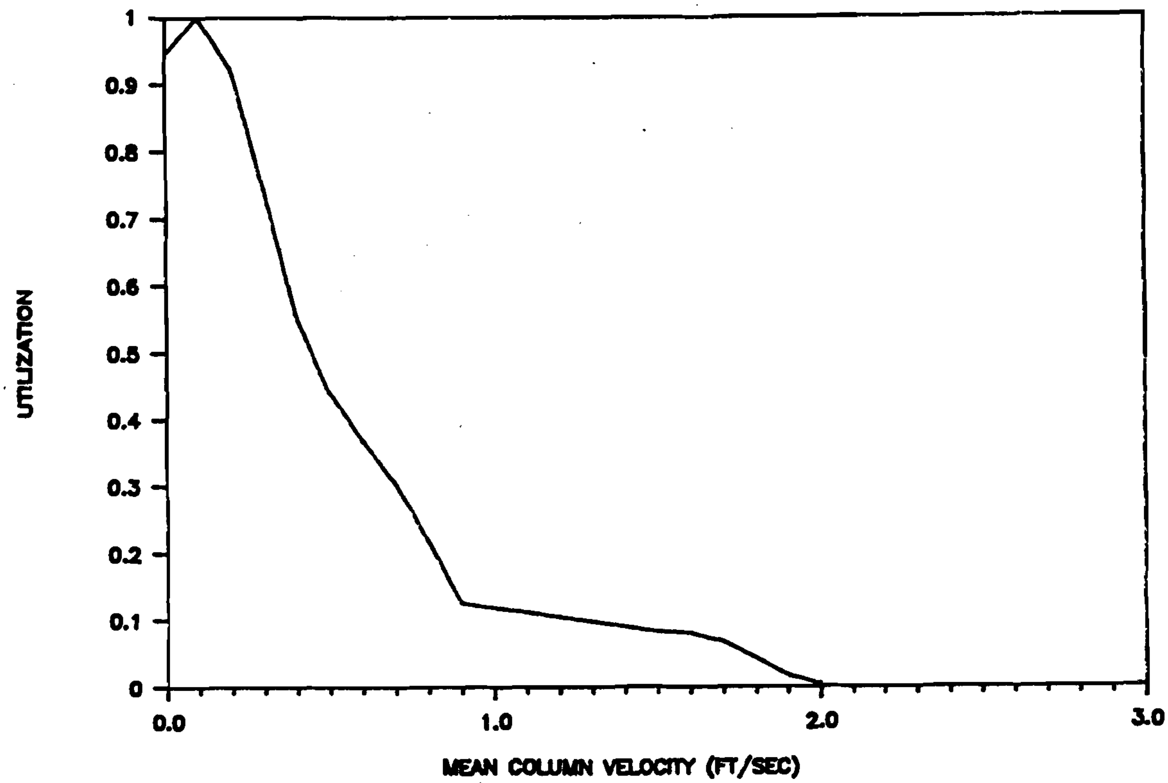
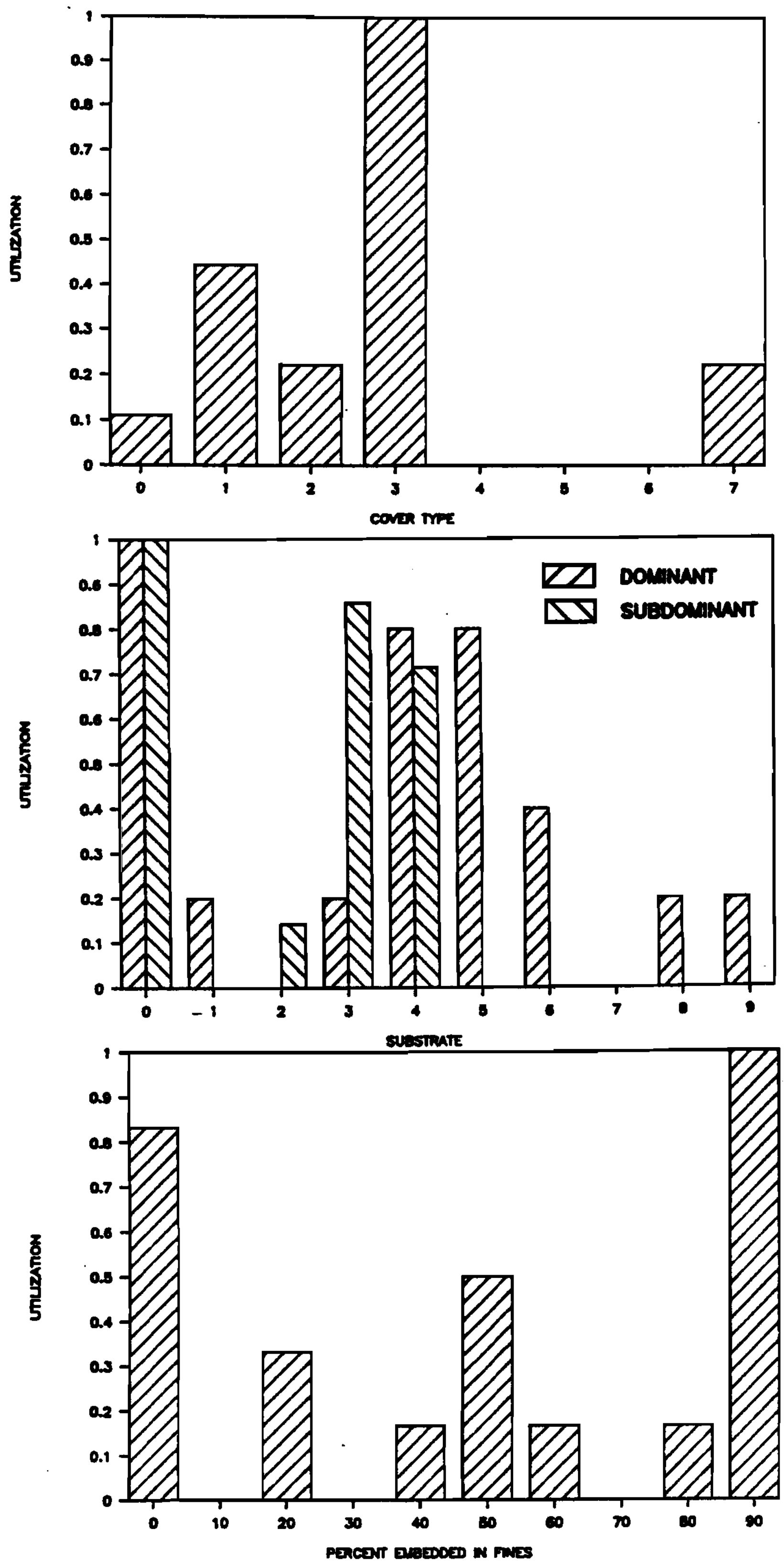
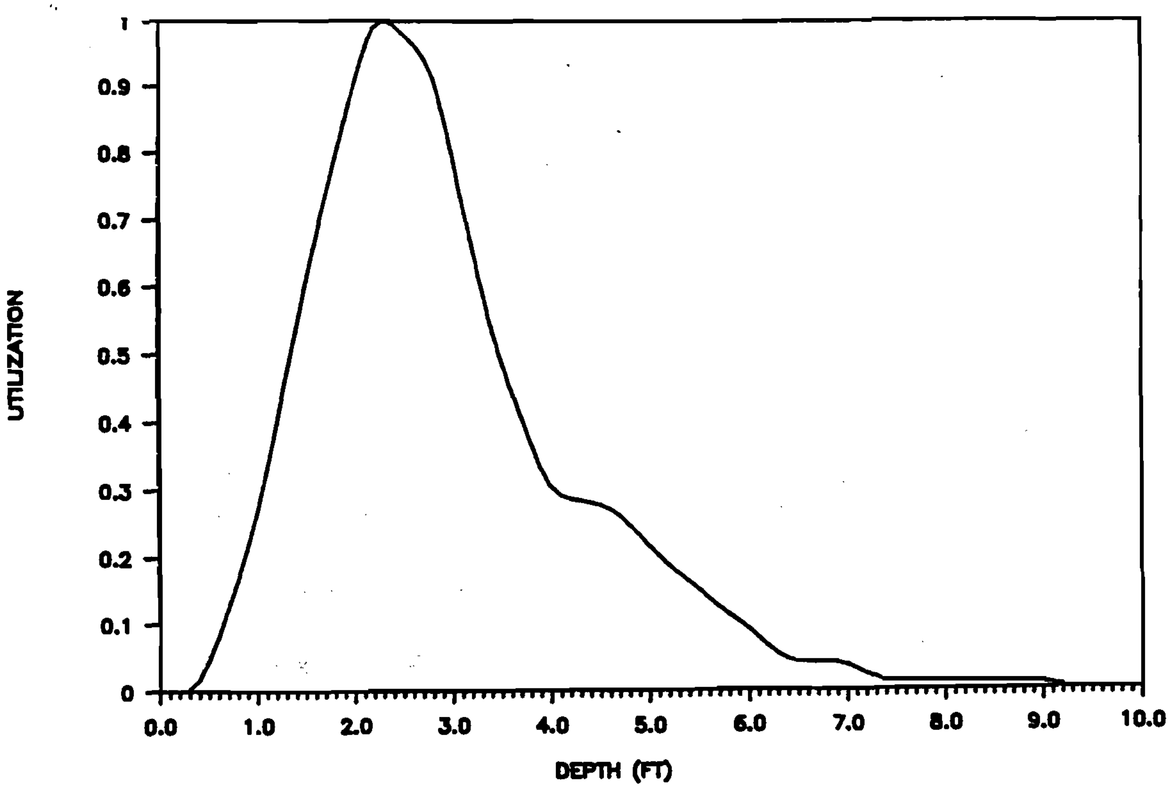


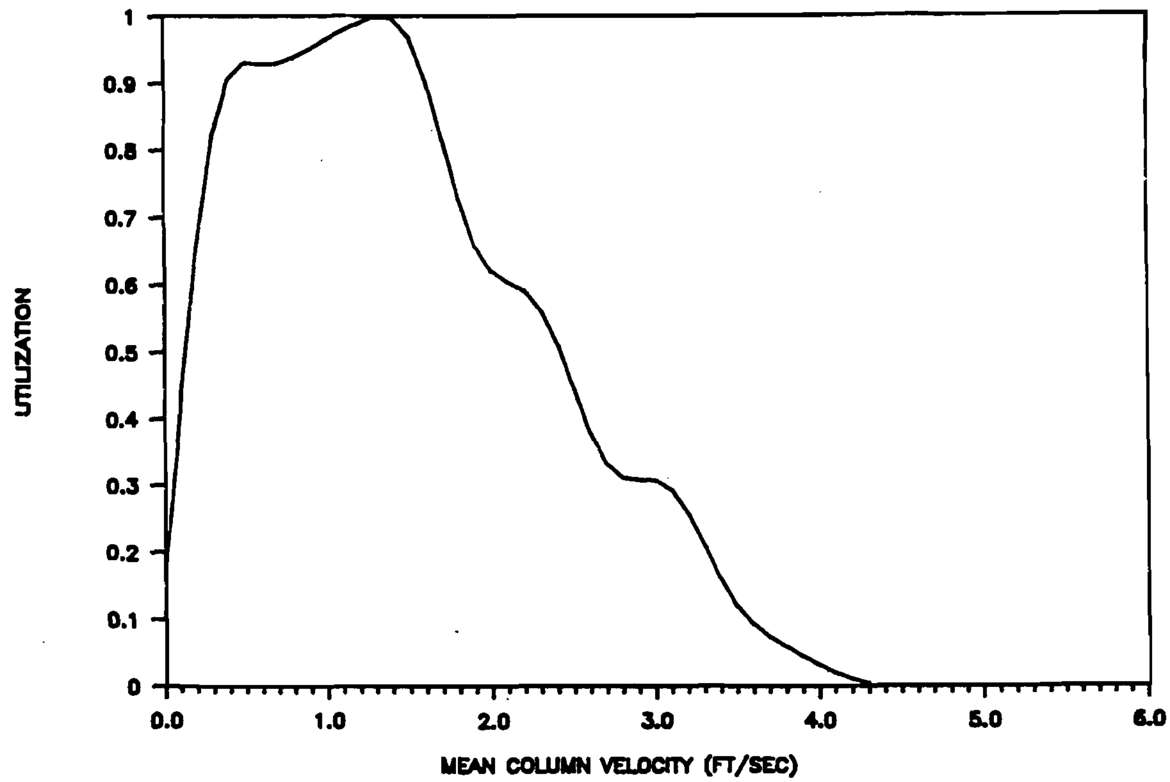


Habitat utilization criteria describing total depths and mean column velocites selcted by steelhead trout fry in the upper Trinity River, CA., 1985-1987.



Habitat utilization criteria describing cover and substrates selected by steelhead trout fry in the upper Trinity River, CA., 1985-1987.





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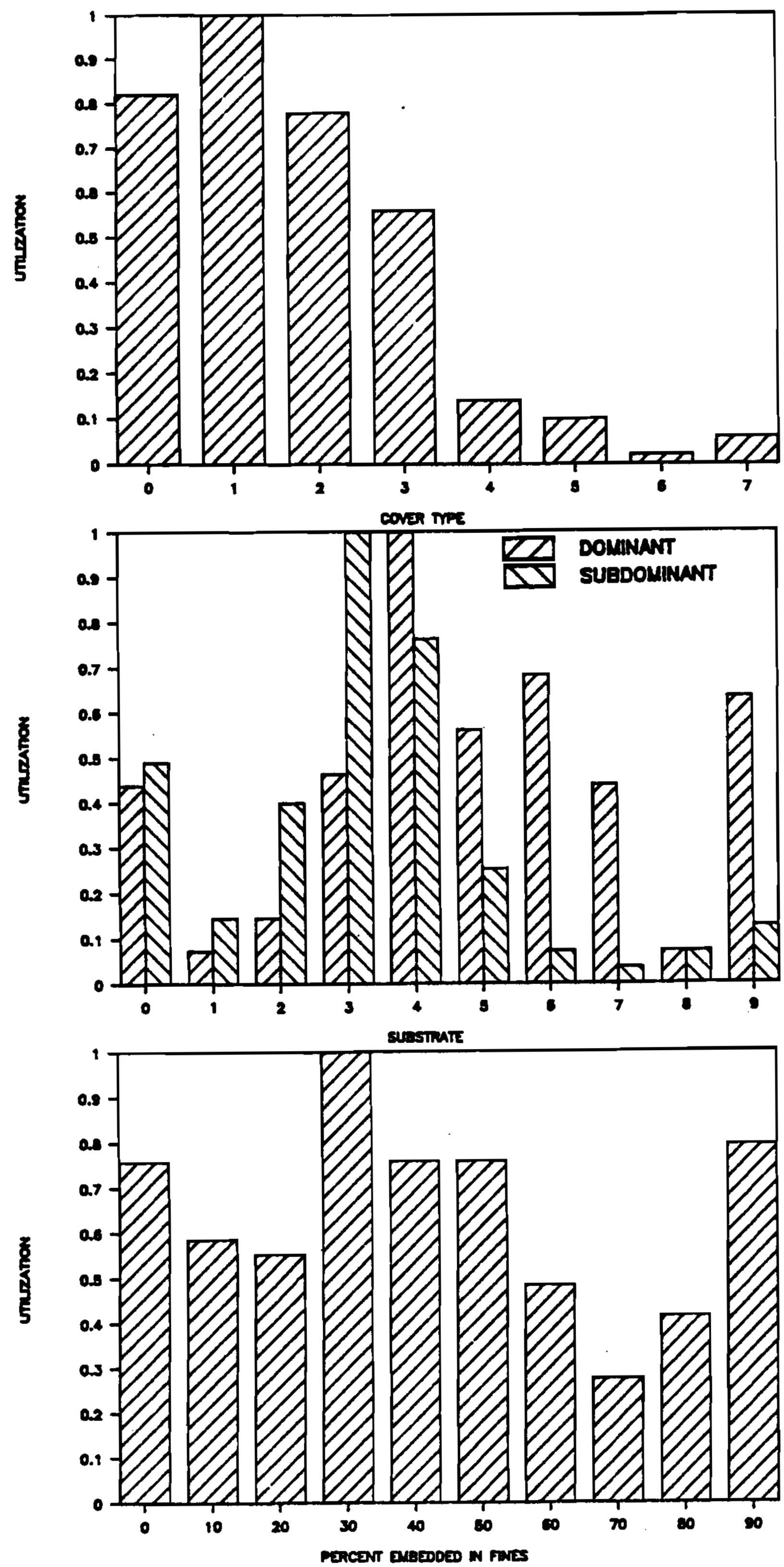
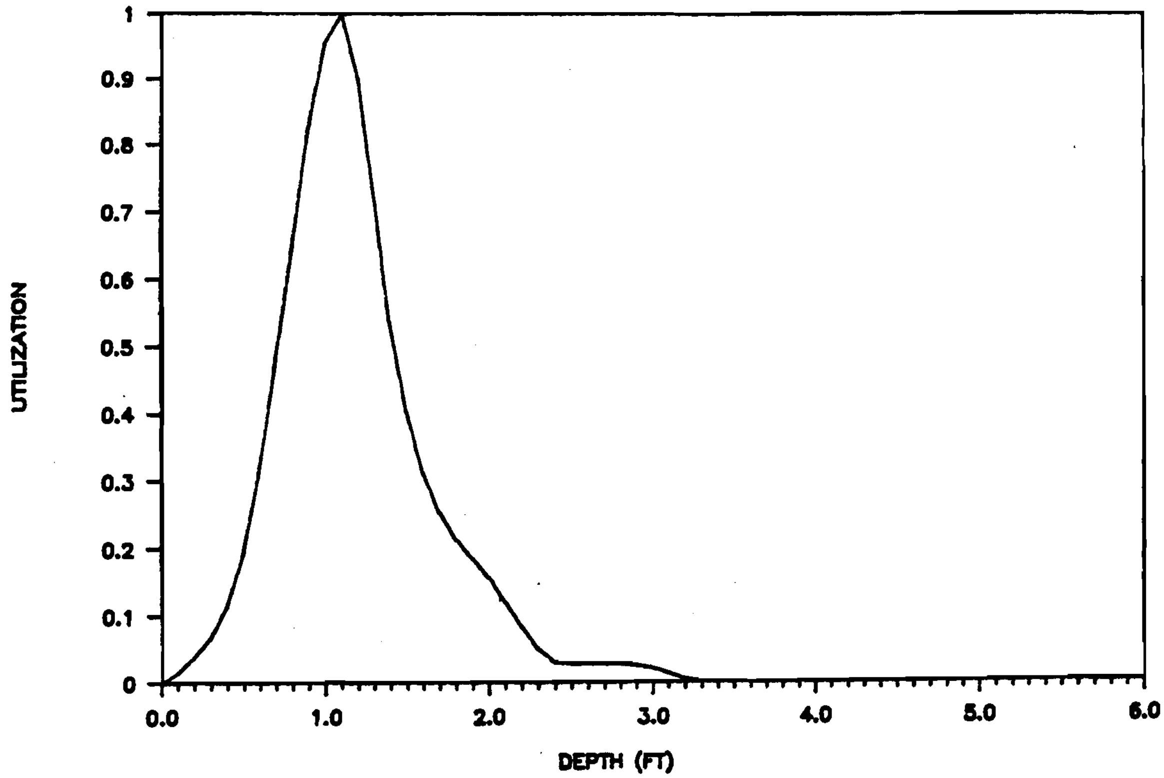
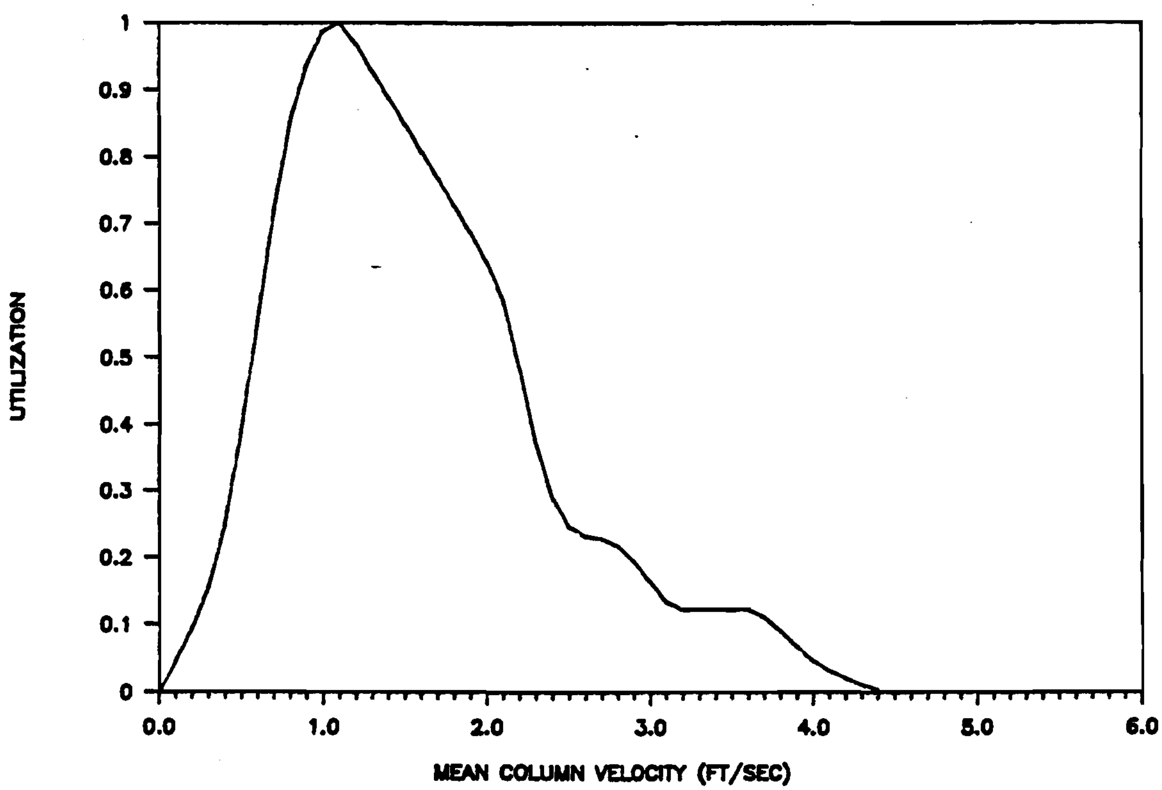
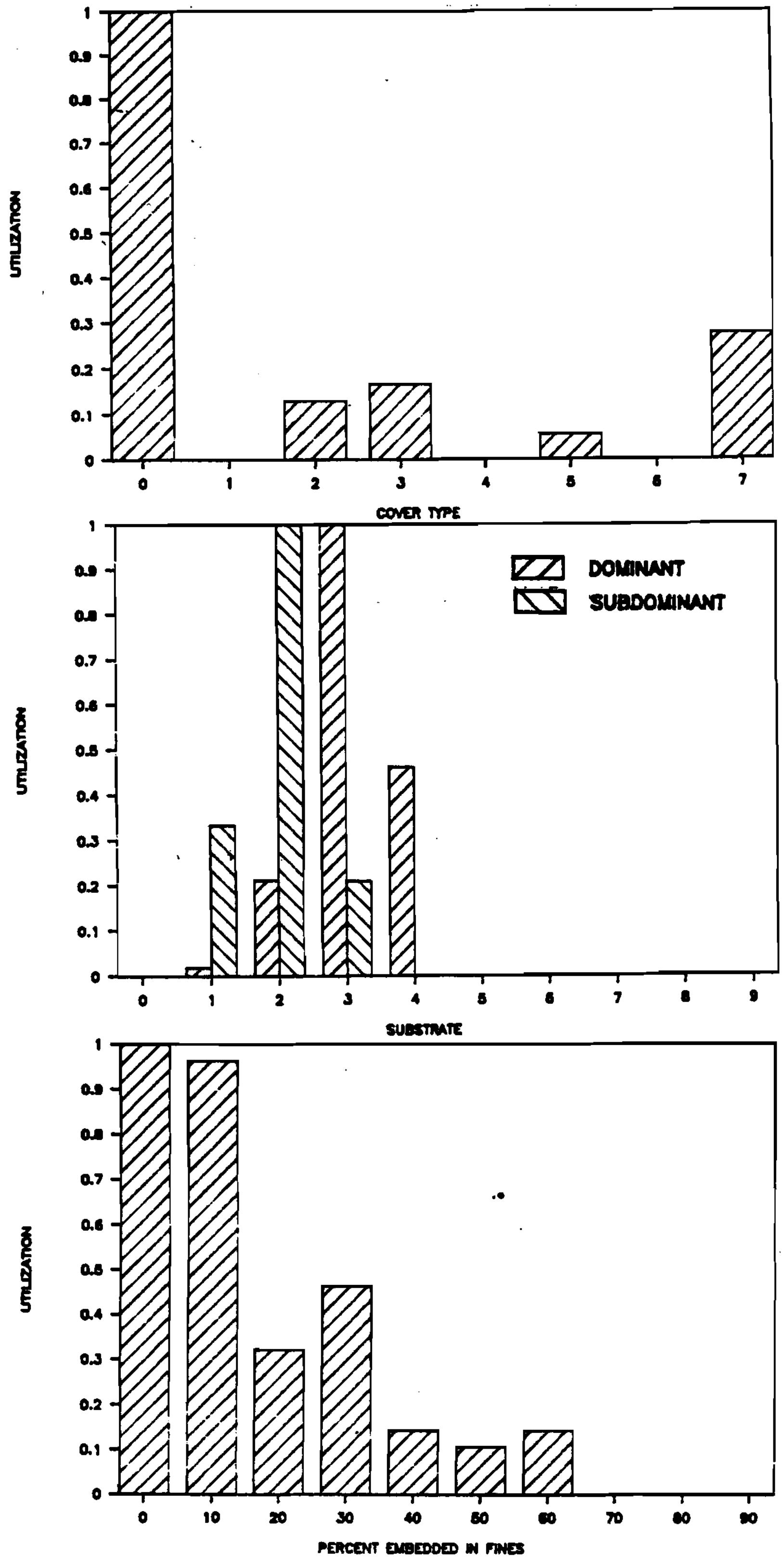


Habitat utilization criteria describing cover and substrates selected by steelhead trout juveniles in the upper Trinity River, CA., 1985-1987.

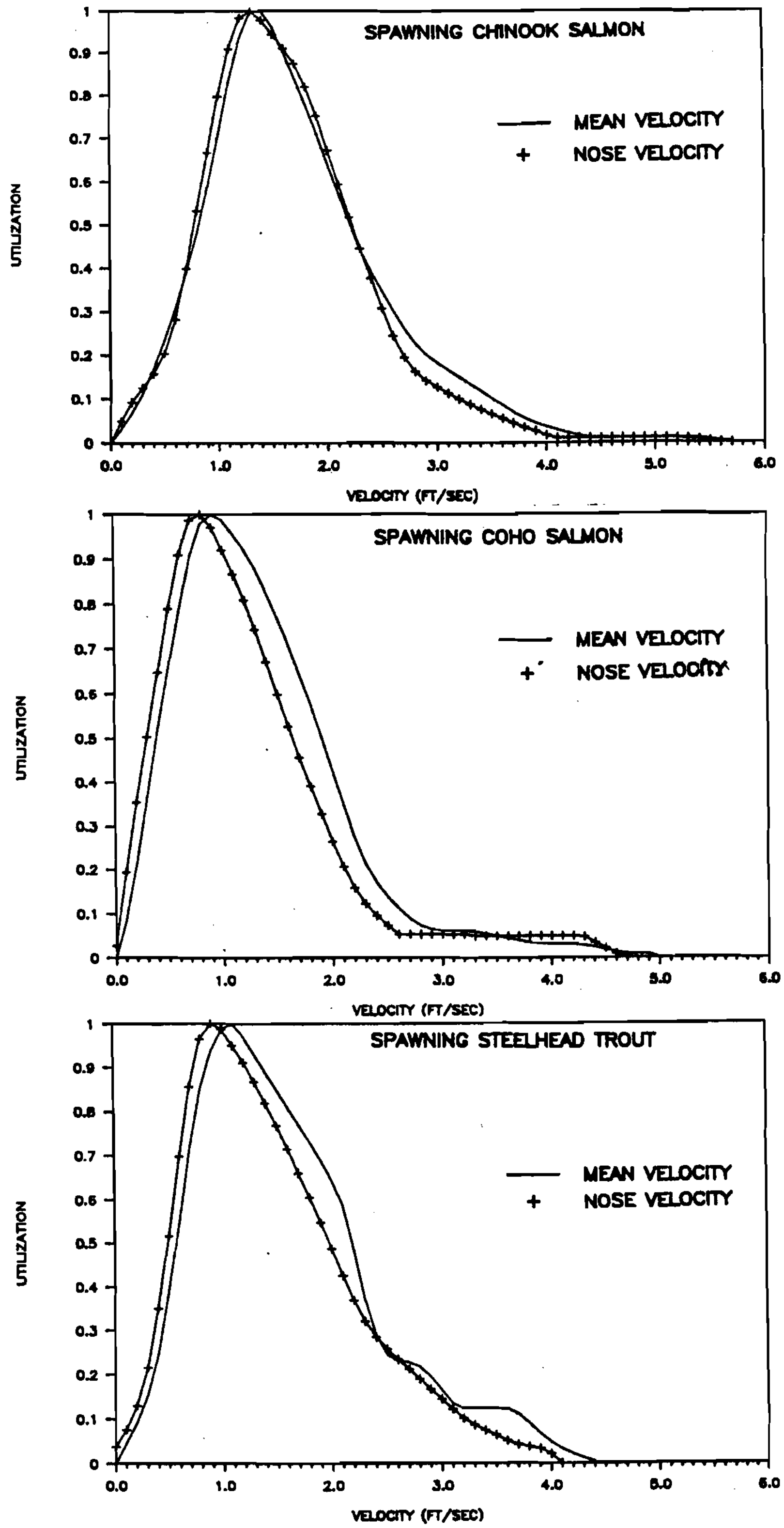




Habitat utilization criteria describing total depths and mean column velocites selcted by spawning steelhead trout in the upper Trinity River, CA., 1985-1987.

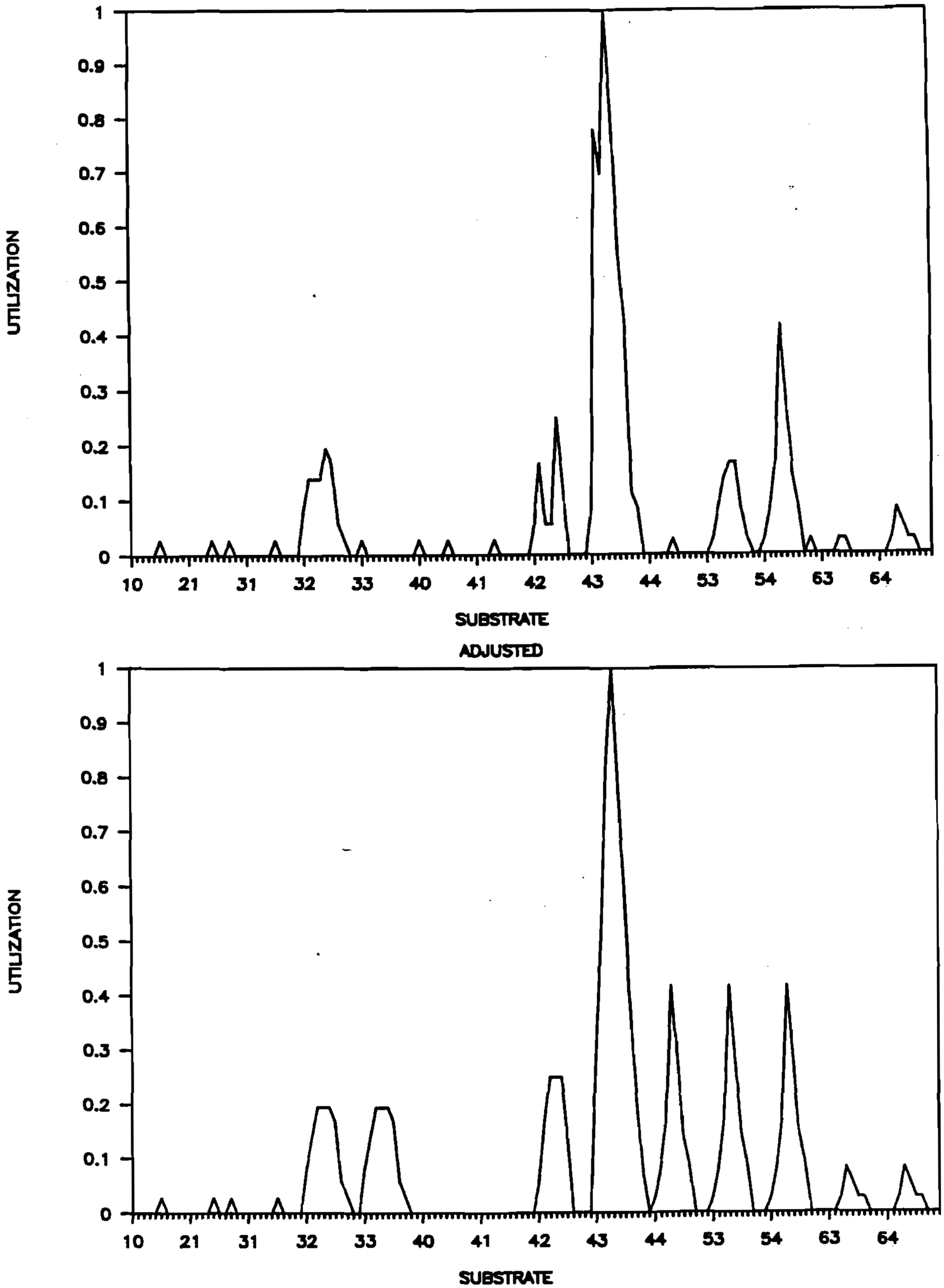


Habitat utilization criteria describing cover and substrates selected by spawning steelhead trout in the upper Trinity River, CA., 1985-1987.



A comparison of habitat utilization criteria developed for fish nose velocities, taken at 0.4 feet, and mean column velocities selected by anadromous salmonids in the upper Trinity River, California, 1985-1987.

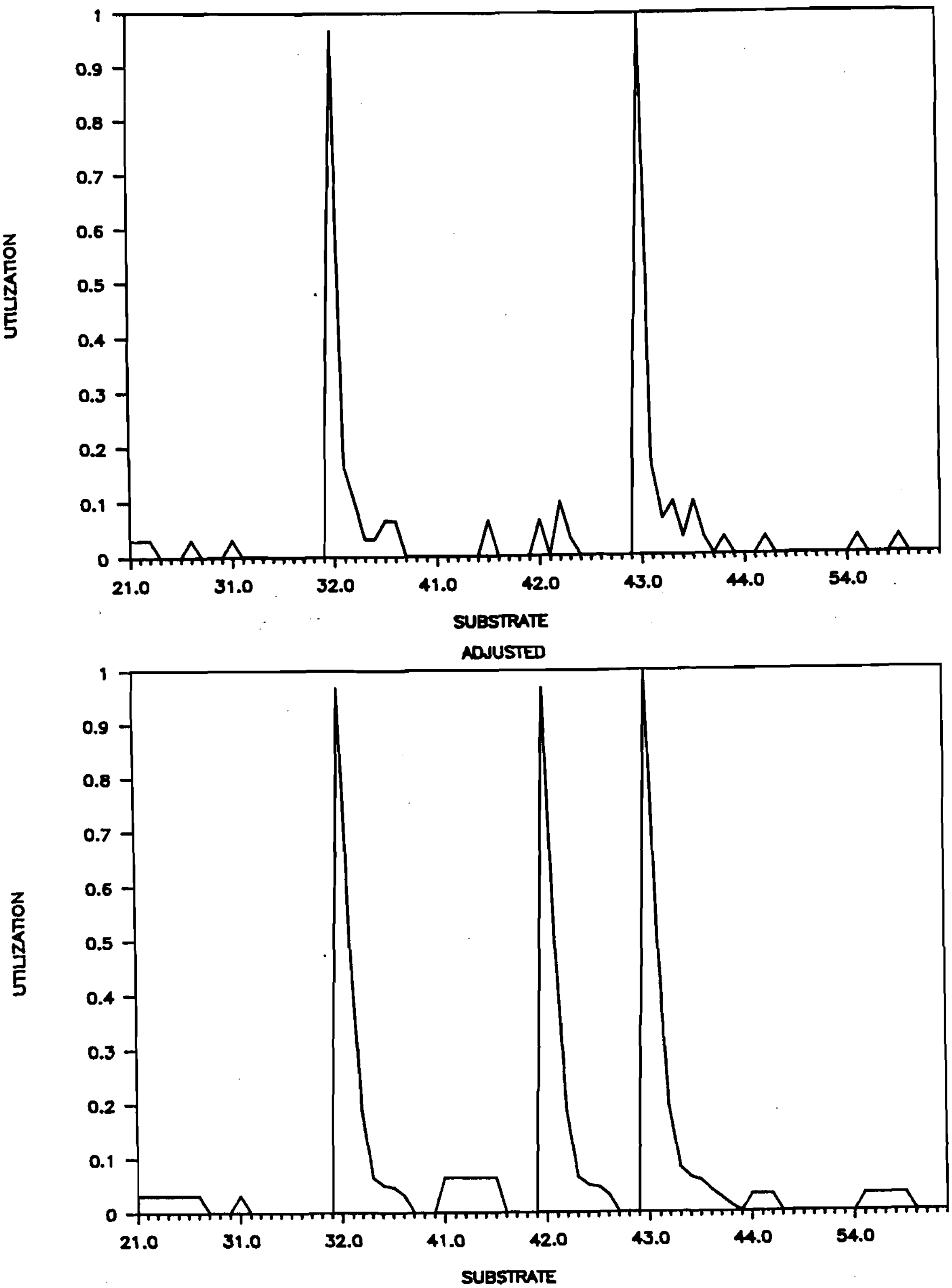
CHINOOK SALMON



Habitat use criteria for substrates selected by spawning chinook salmon in the upper Trinity River as described with the Brusven Index. Use criteria as calculated is shown in the upper half of the Figure and adjusted use criteria is shown in the lower half of the Figure.

APPENDIX C

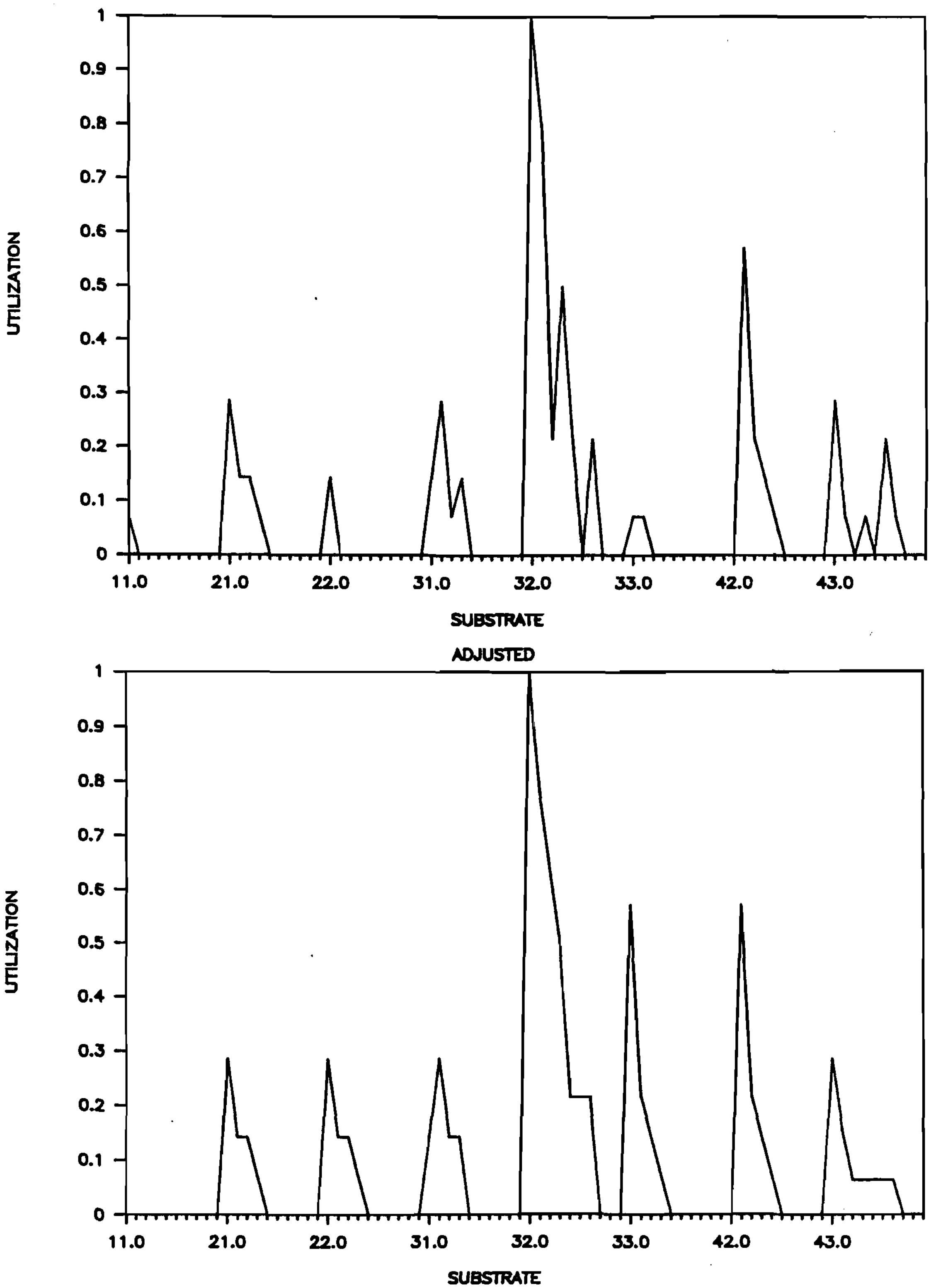
COHO SALMON



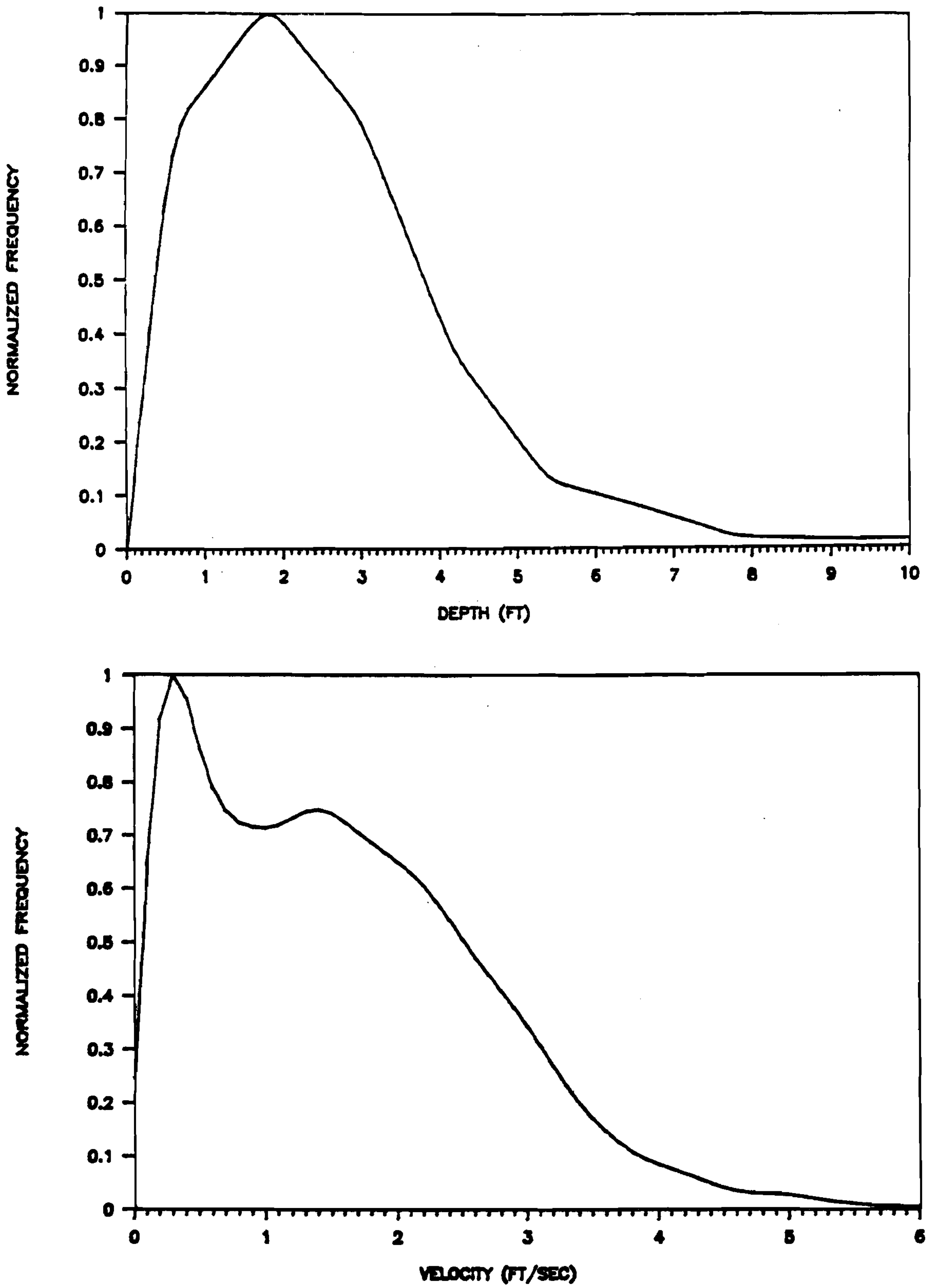
Habitat use criteria for substrates selected by spawning coho salmon in the upper Trinity River as described with the Brusven Index. Use criteria as calculated is shown in the upper half of the Figure and adjusted use criteria is shown in the lower half of the Figure.

APPENDIX C

STEELHEAD TROUT

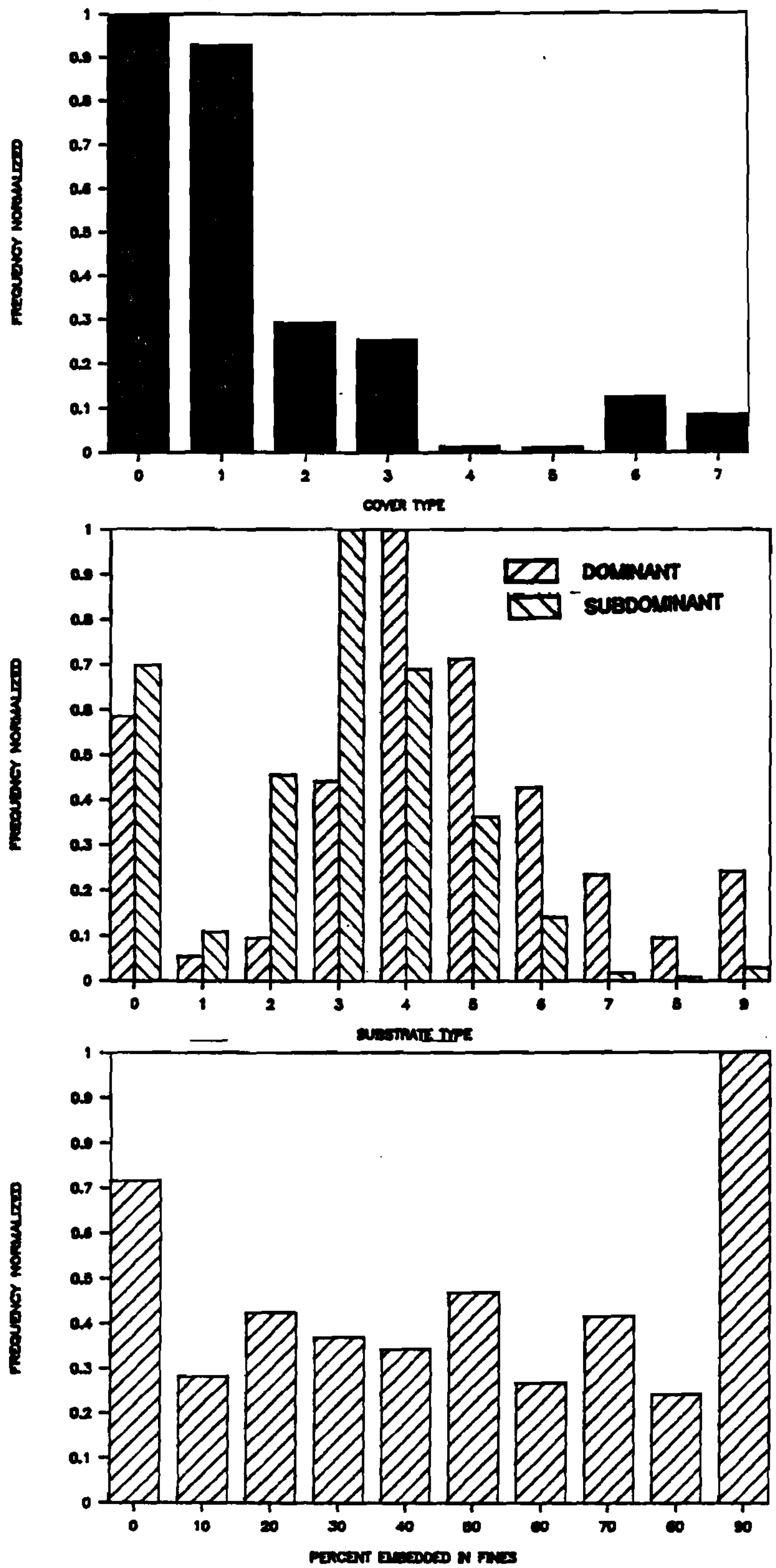


Habitat use criteria for substrates selected by spawning steelhead trout in the upper Trinity River as described with the Brusven Index. Use criteria as calculated is shown in the upper half of the Figure and adjusted use criteria is shown in the lower half of the Figure.

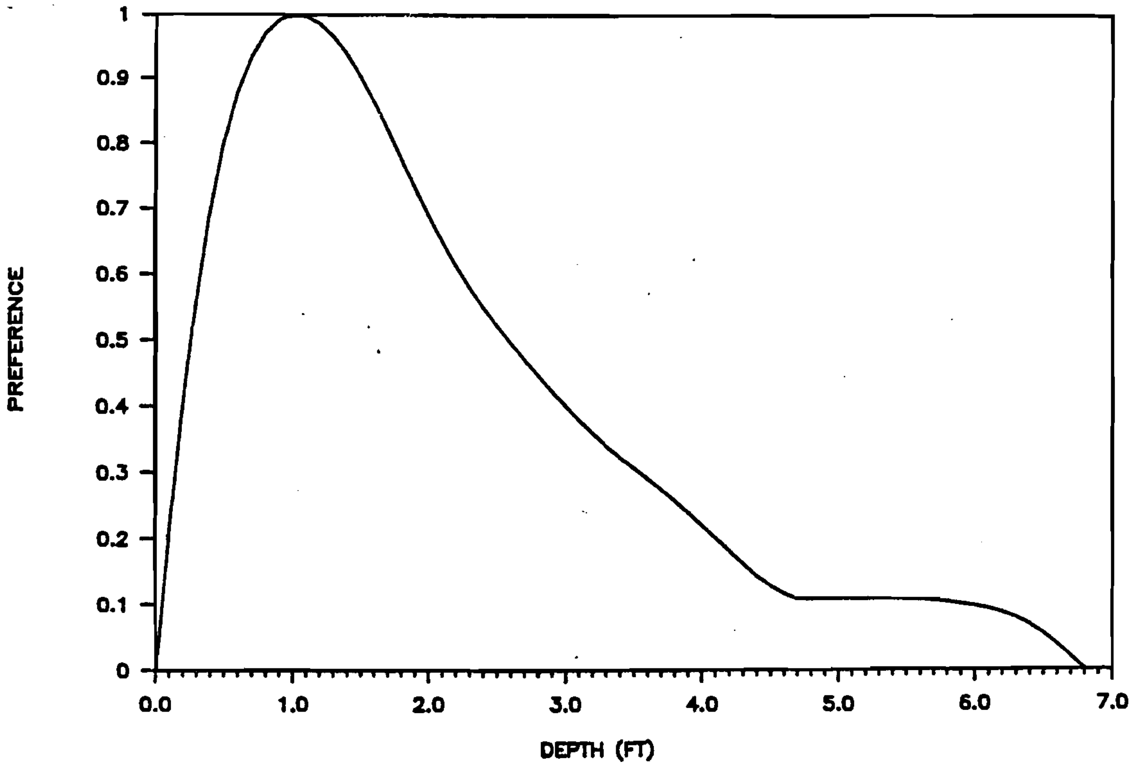


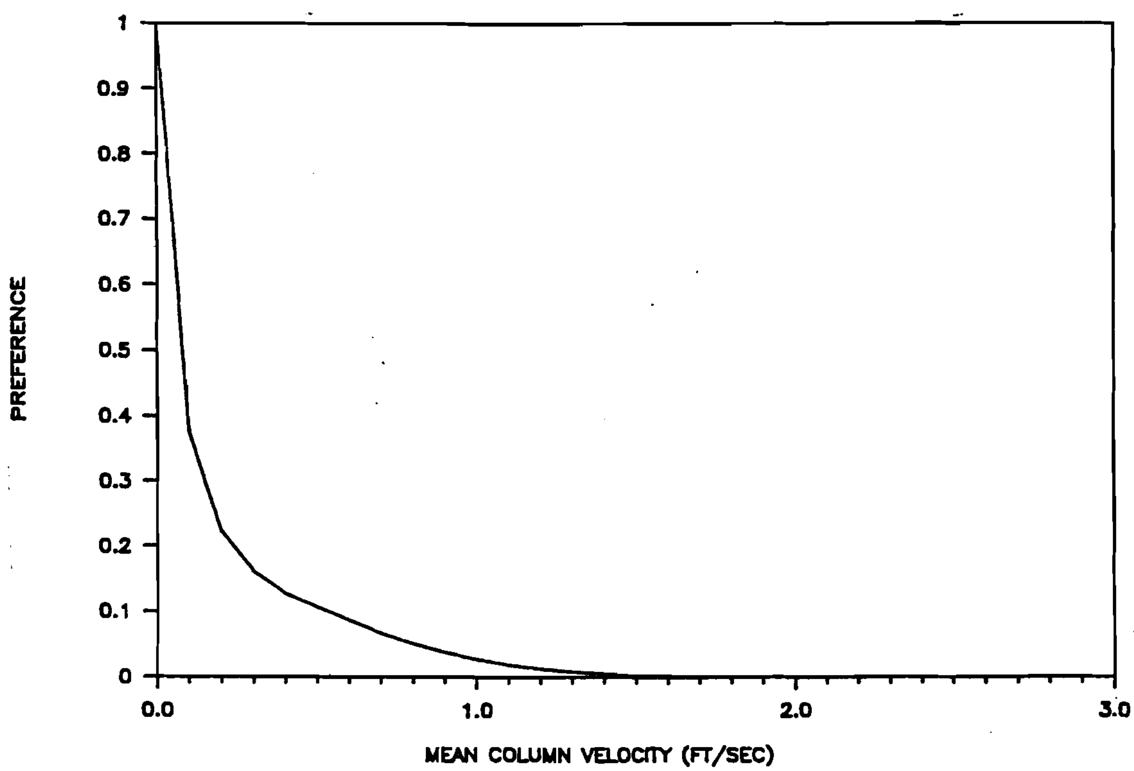
Estimates of habitat availability for total depth and mean column velocity taken from the IFG-4 program of the Instream Flow Incremental Methodology, Trinity River, CA.

APPENDIX D



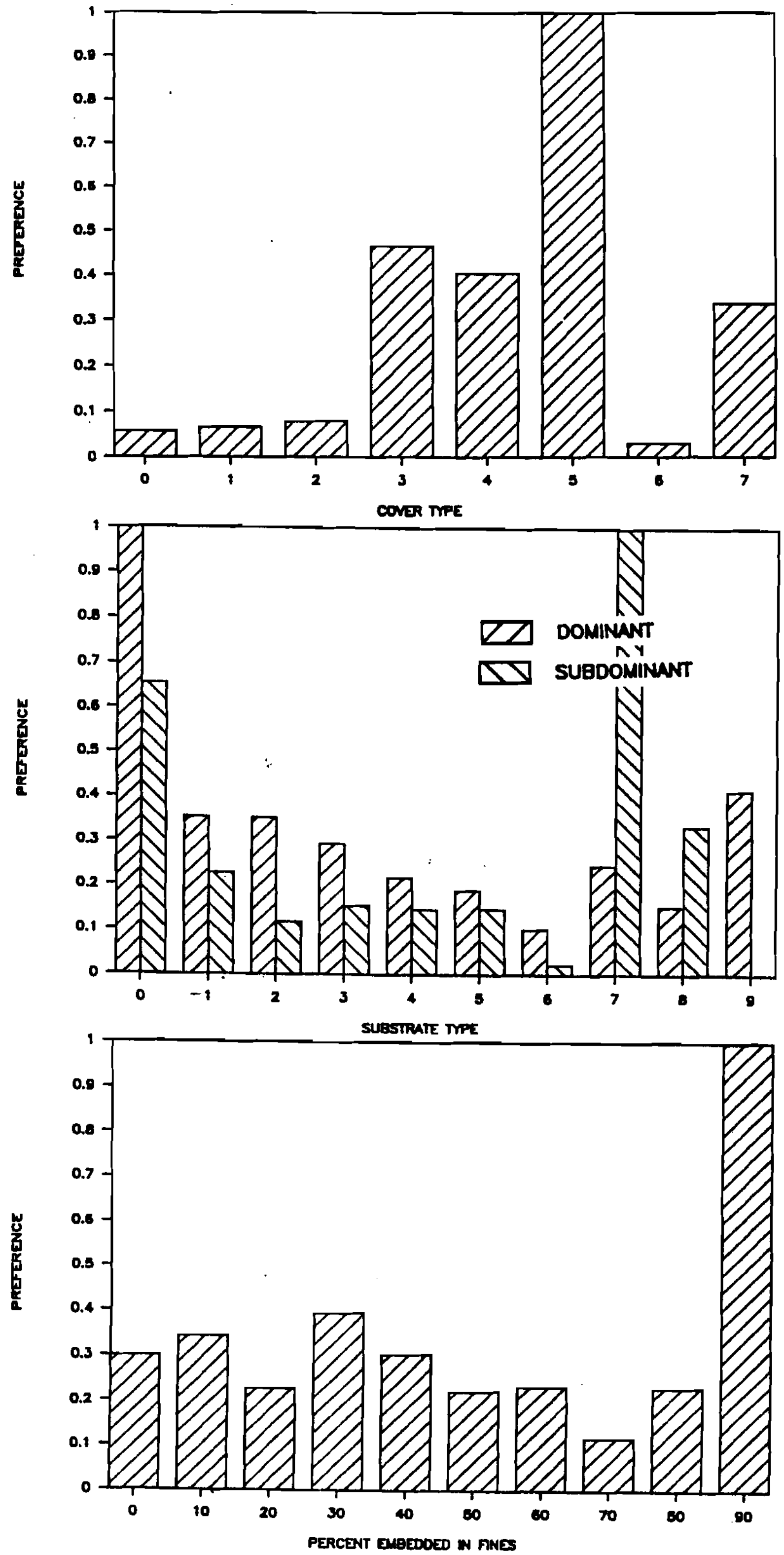
Estimates of habitat availability for cover and substrate taken from the IFG-4 program of the Instream Flow Incremental Methodology, Trinity River, CA.



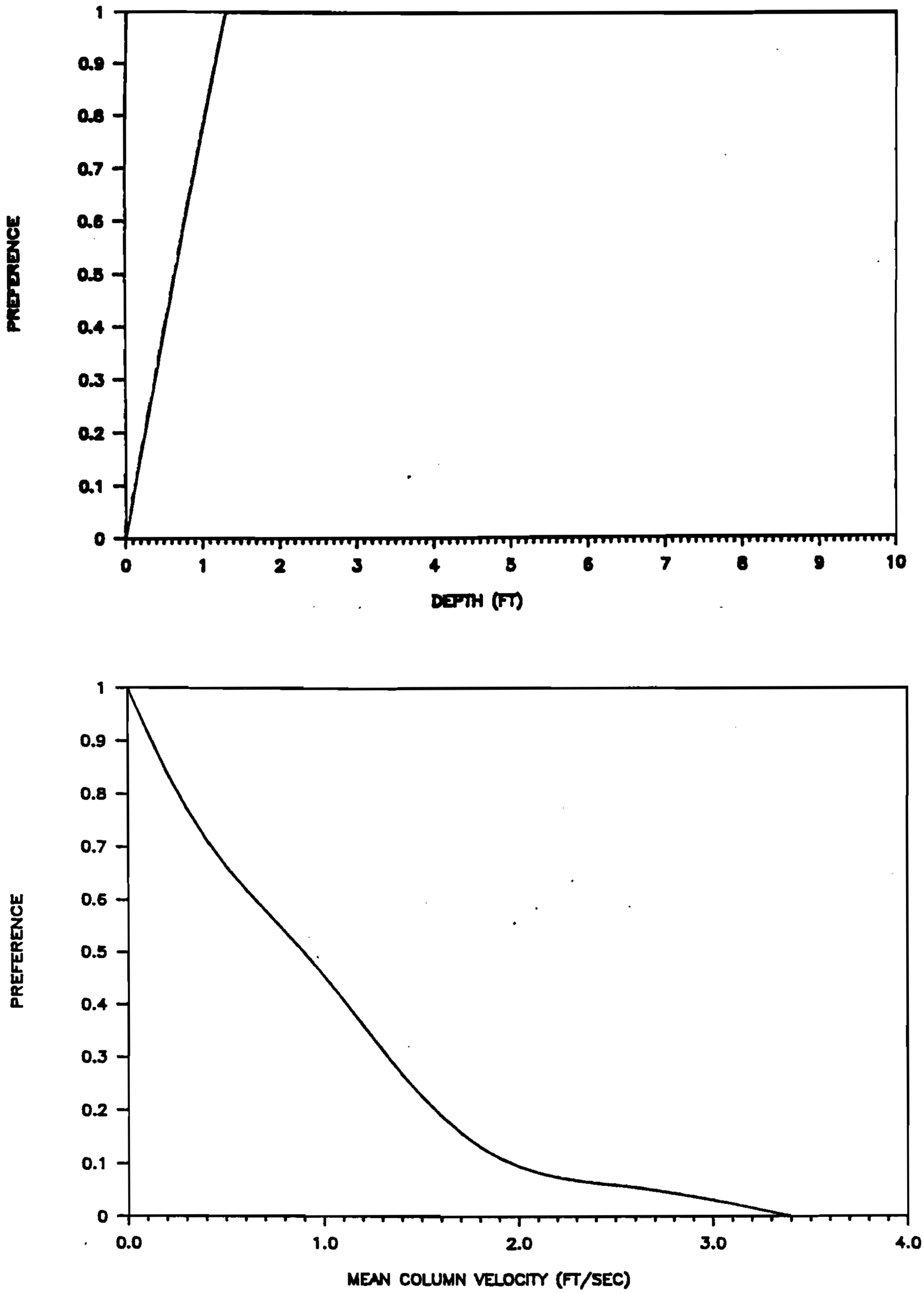


Final habitat preference criteria describing total depths and mean column velocities selected by chinook salmon fry in the upper Trinity River, CA., 1985-1987

APPENDIX E

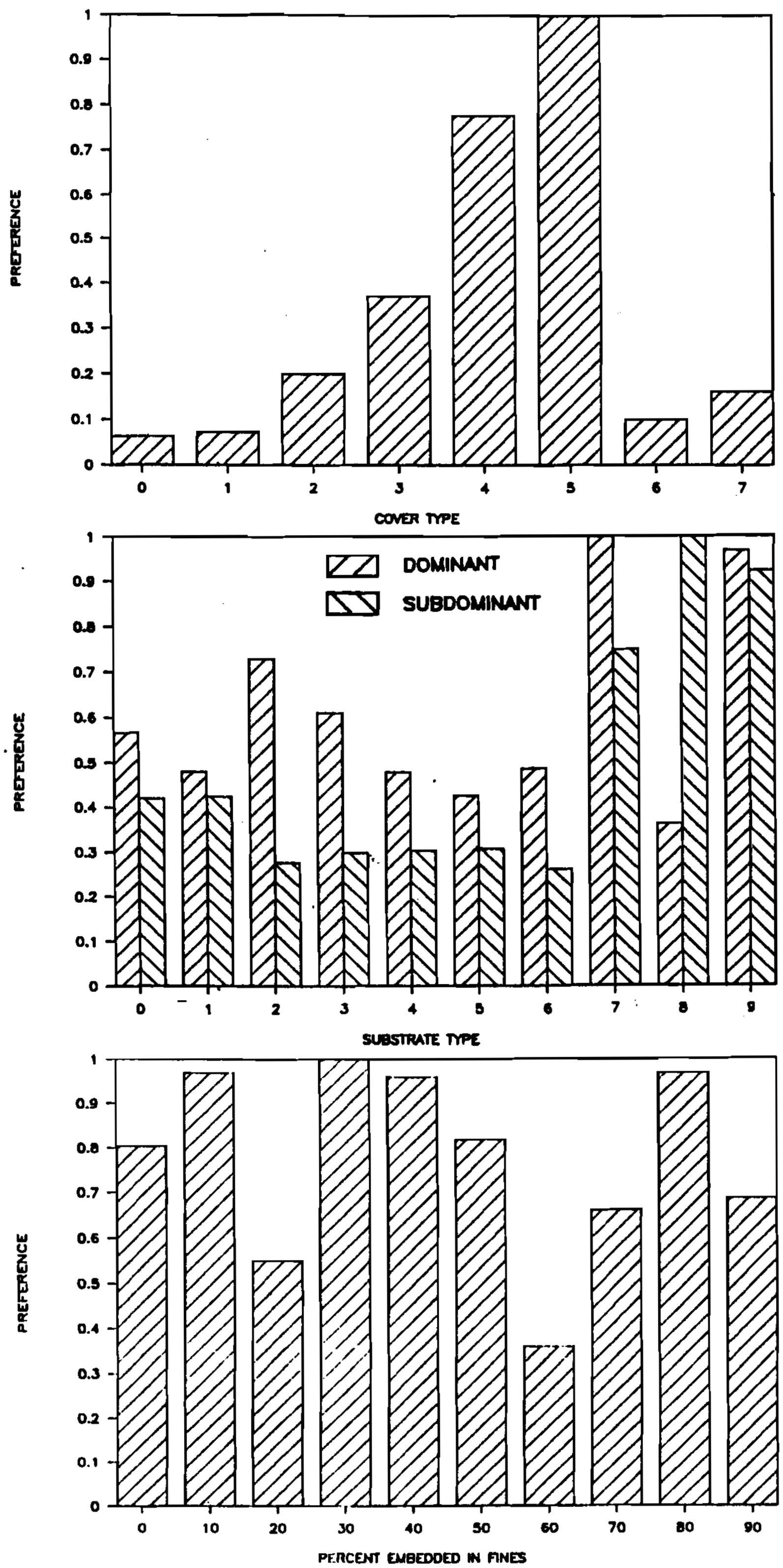


Final habitat preference criteria describing cover and substrates selected by chinook salmon fry in the upper Trinity River, CA., 1985-1987.

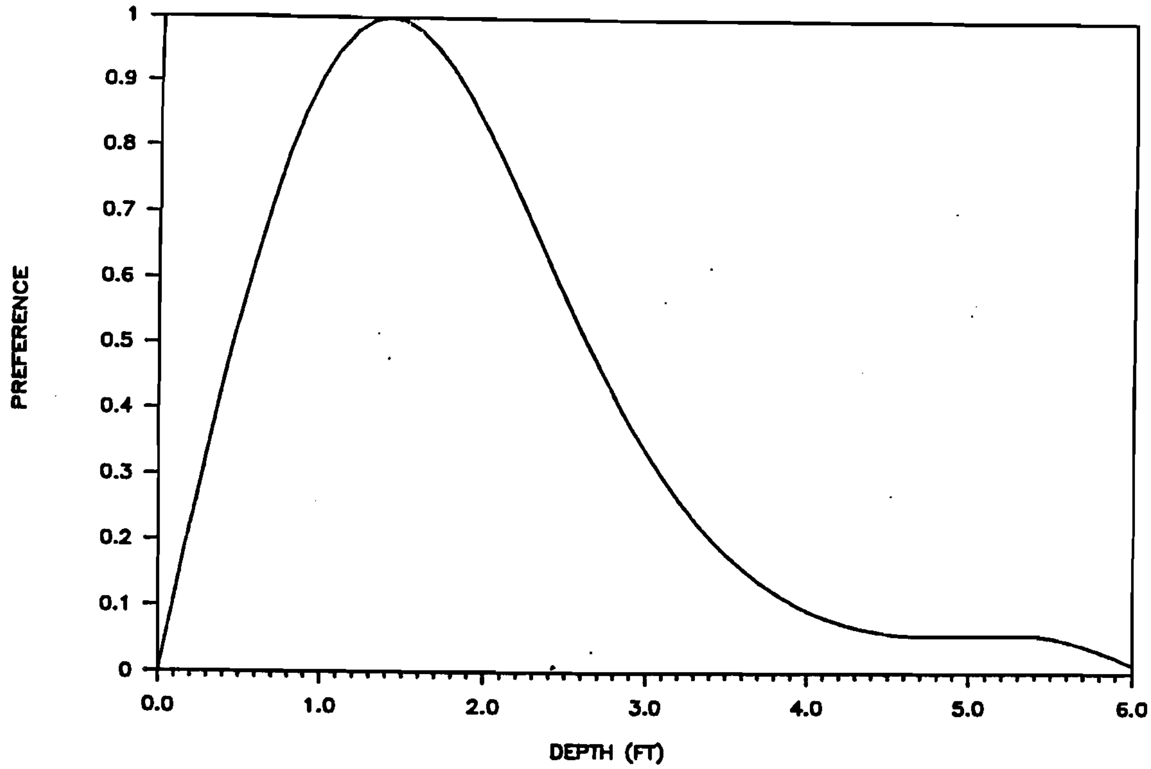


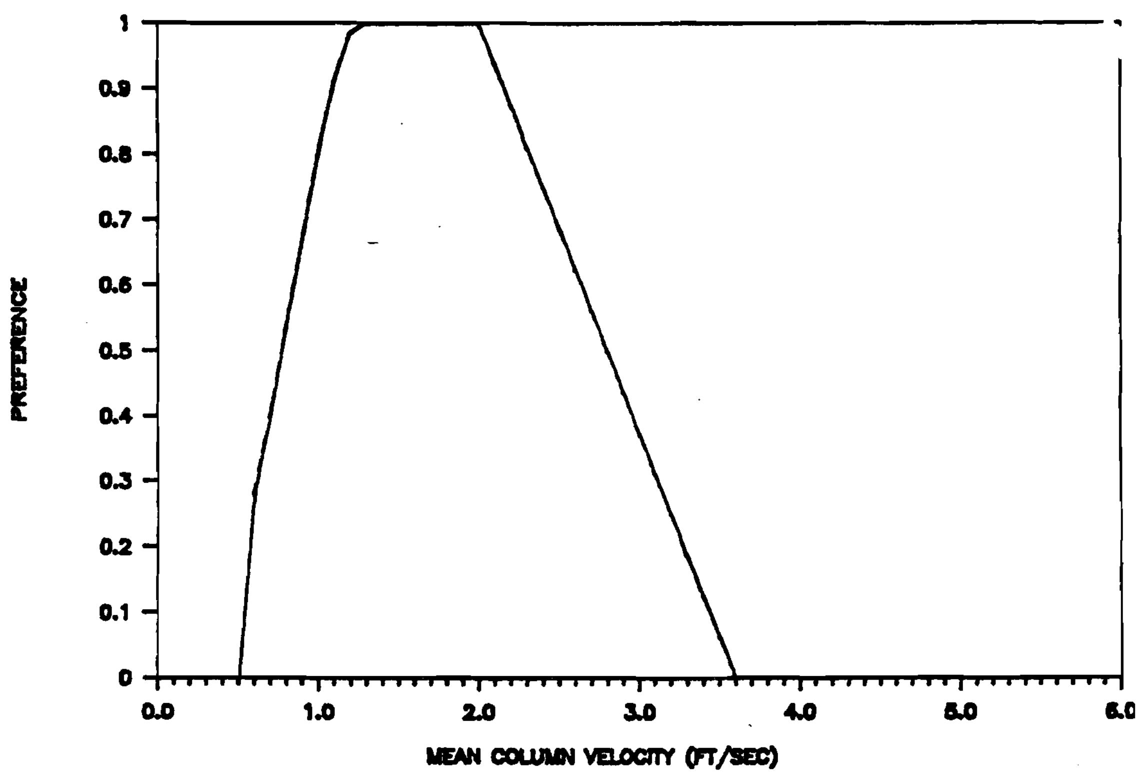
Final habitat preference criteria describing total depths and mean column velocities selected by chinook salmon juveniles in the upper Trinity River, CA., 1985-1987.

APPENDIX E



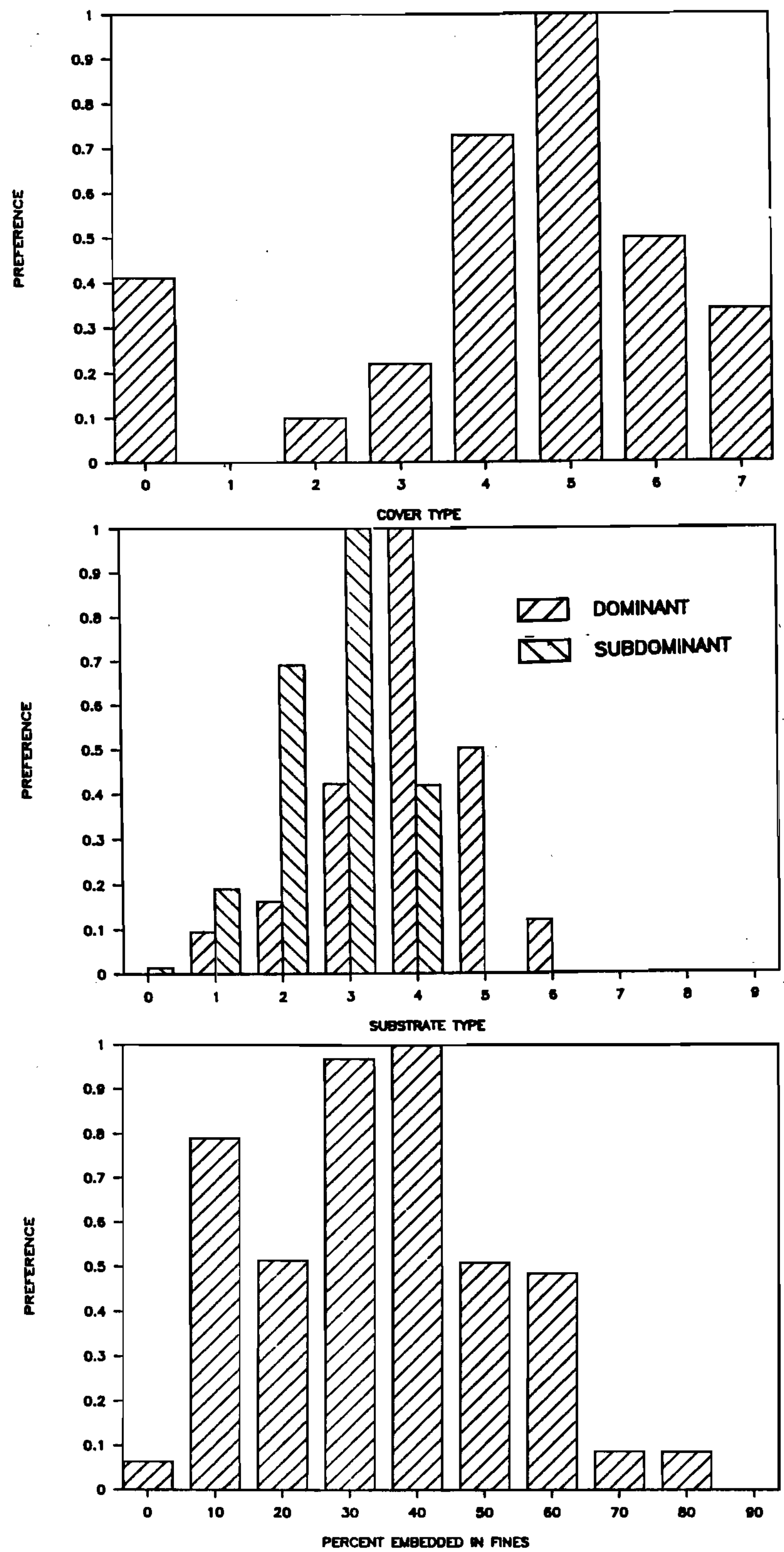
Final habitat preference criteria describing cover and substrates selected by chinook salmon juveniles in the upper Trinity River, CA., 1985-1987.



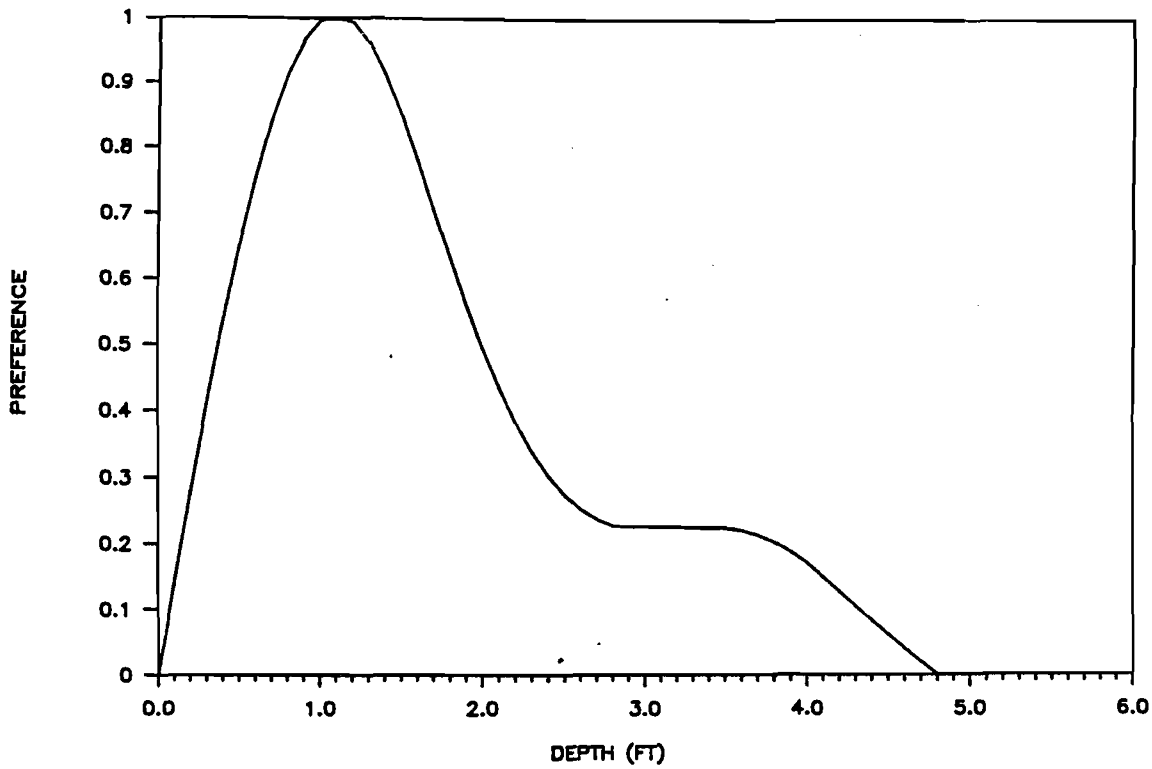


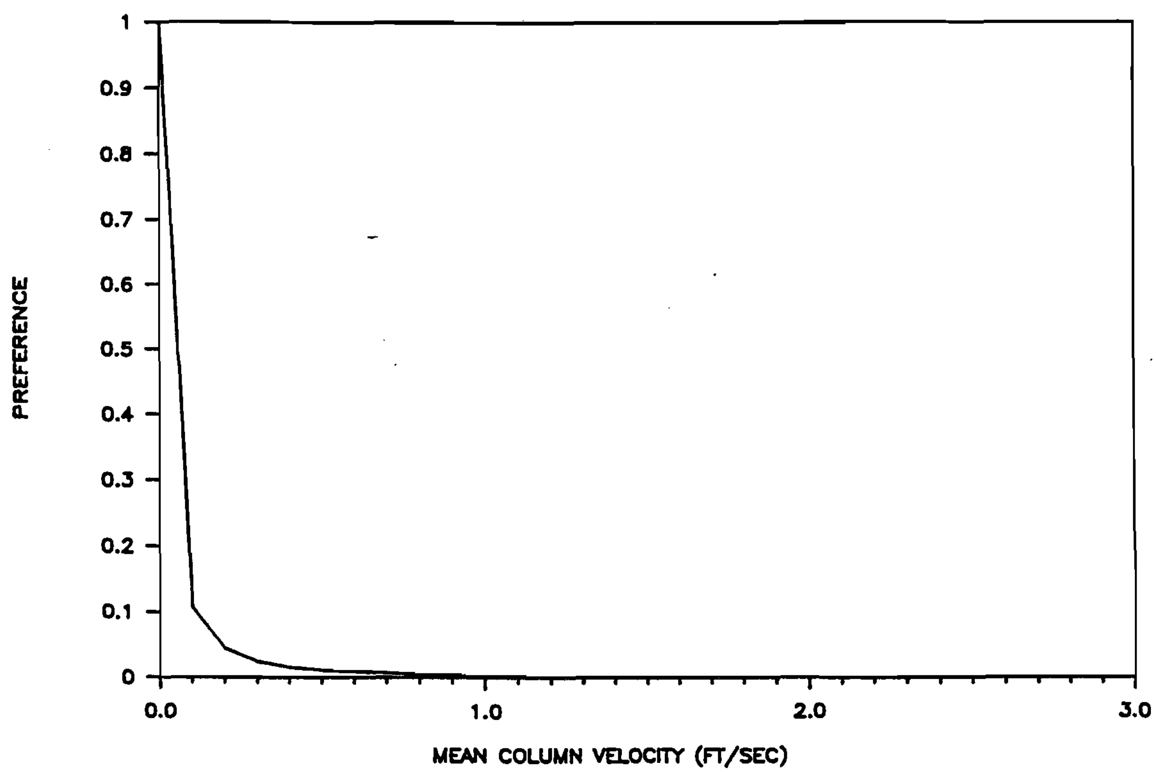
Final habitat preference criteria describing total depths and mean column velocities selected by spawning chinook salmon in the upper Trinity River, CA., 1985-1987.

APPENDIX E



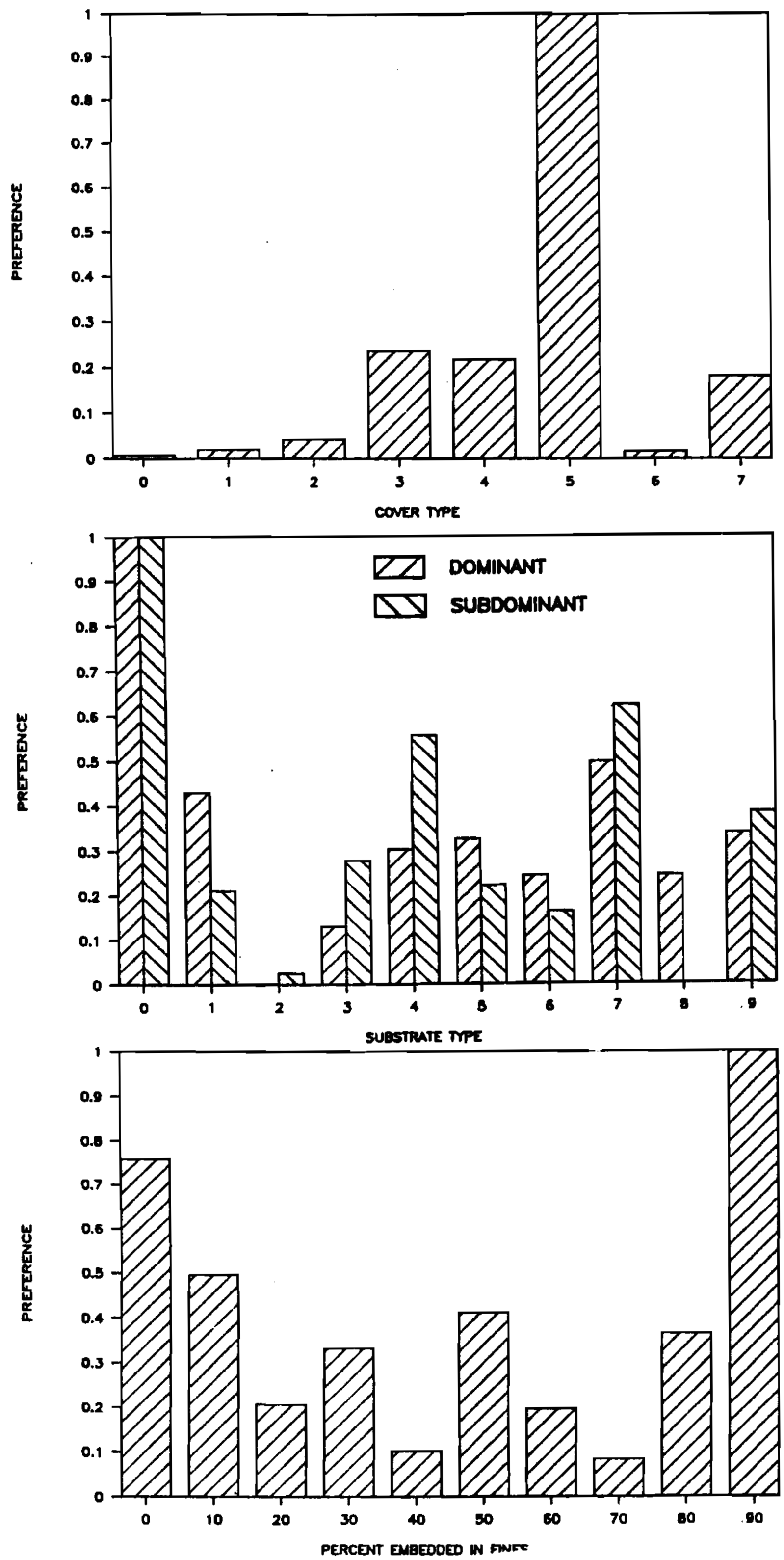
Final habitat preference criteria describing cover and substrates selected by spawning chinook salmon in the upper Trinity River, CA., 1985-1987.



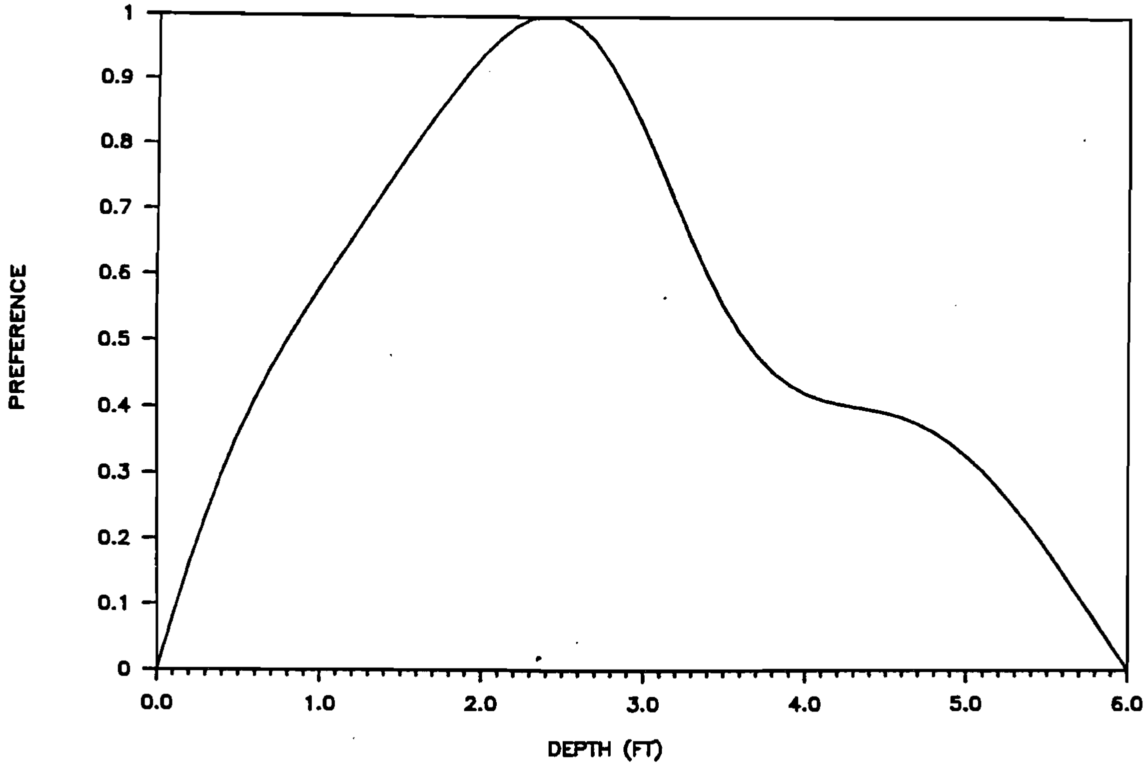


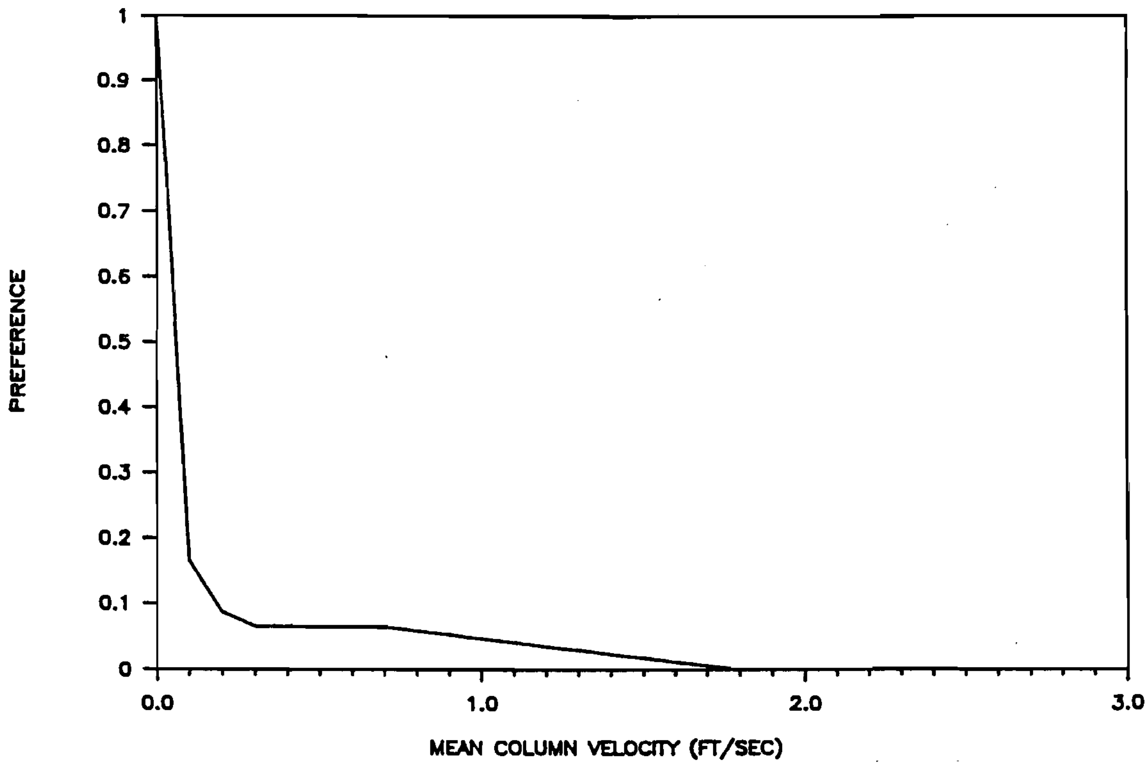
Final habitat preference criteria describing total depths and mean column velocities selected by coho salmon fry in the upper Trinity River, CA., 1985-1987.

APPENDIX E



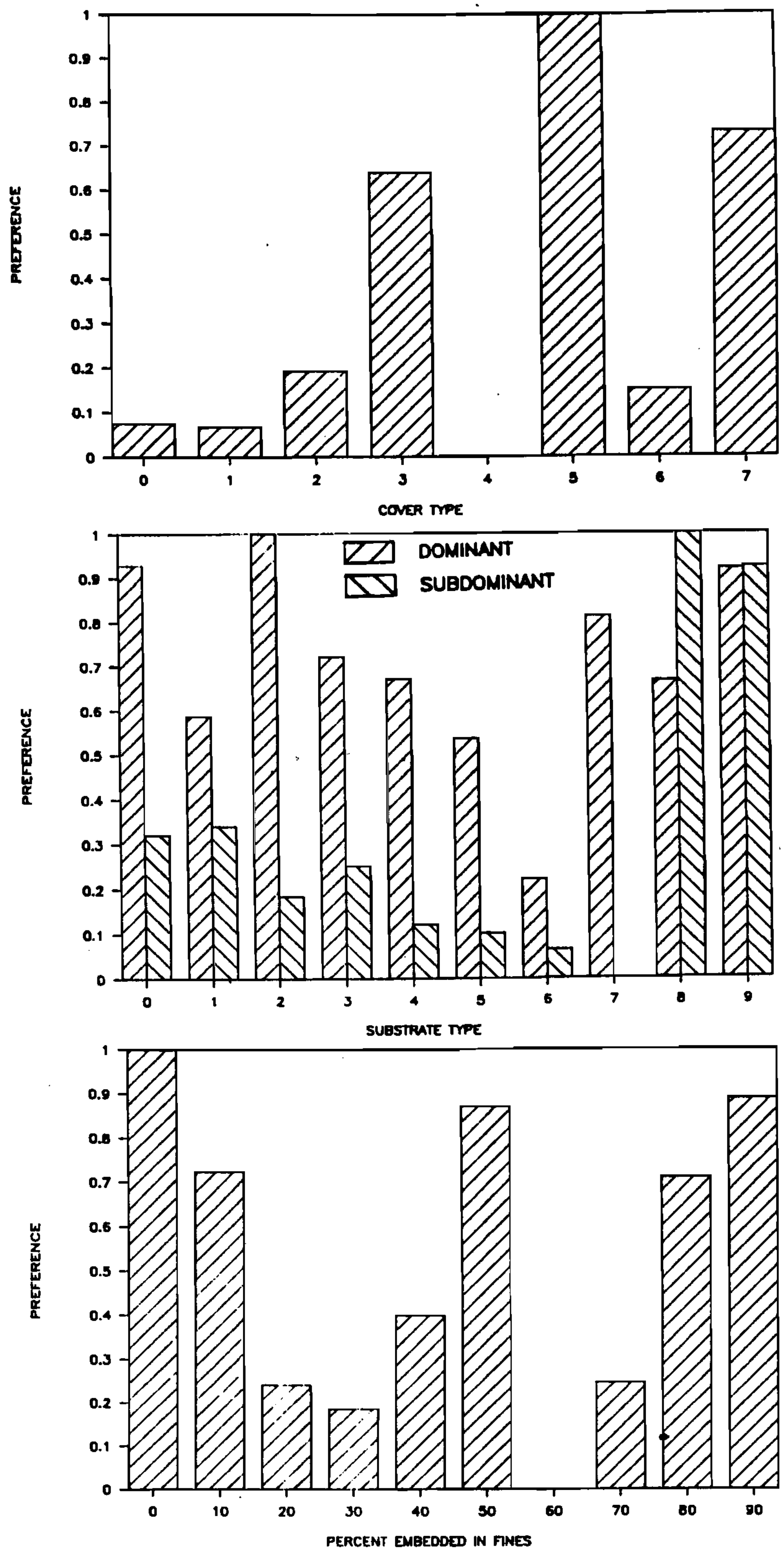
Final habitat preference criteria describing cover and substrates selected by coho salmon fry in the upper Trinity River, CA., 1985-1987.



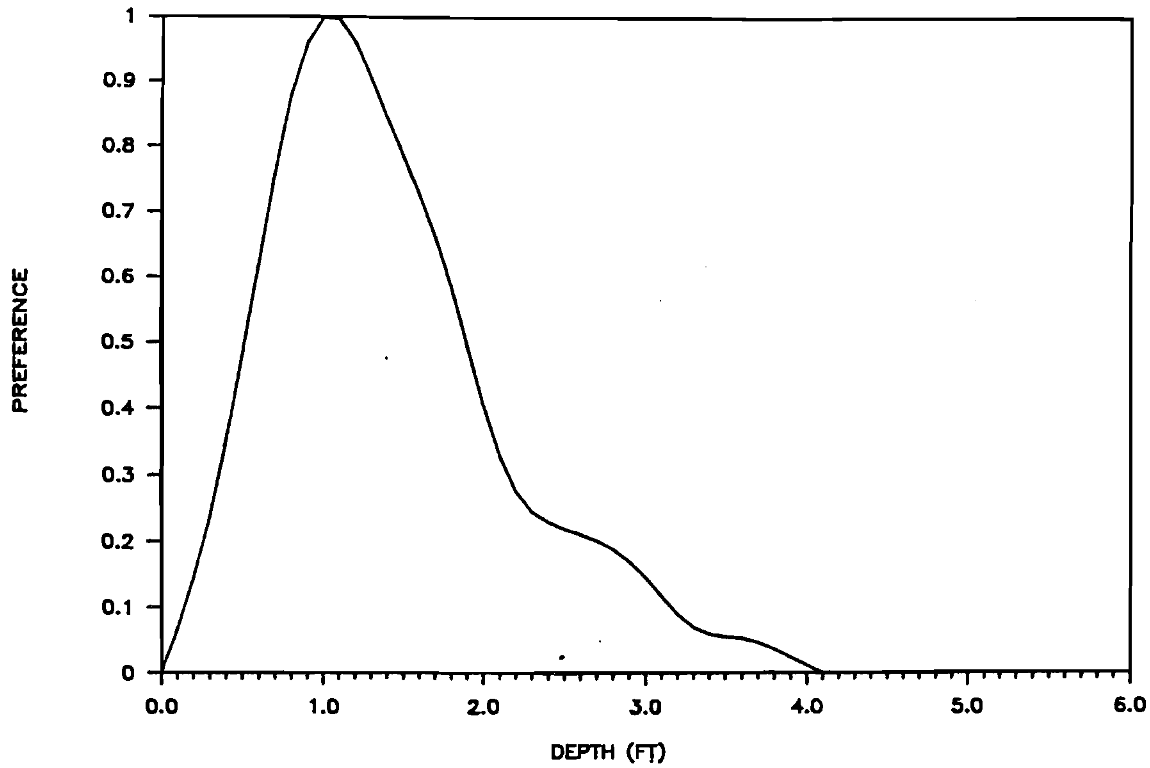


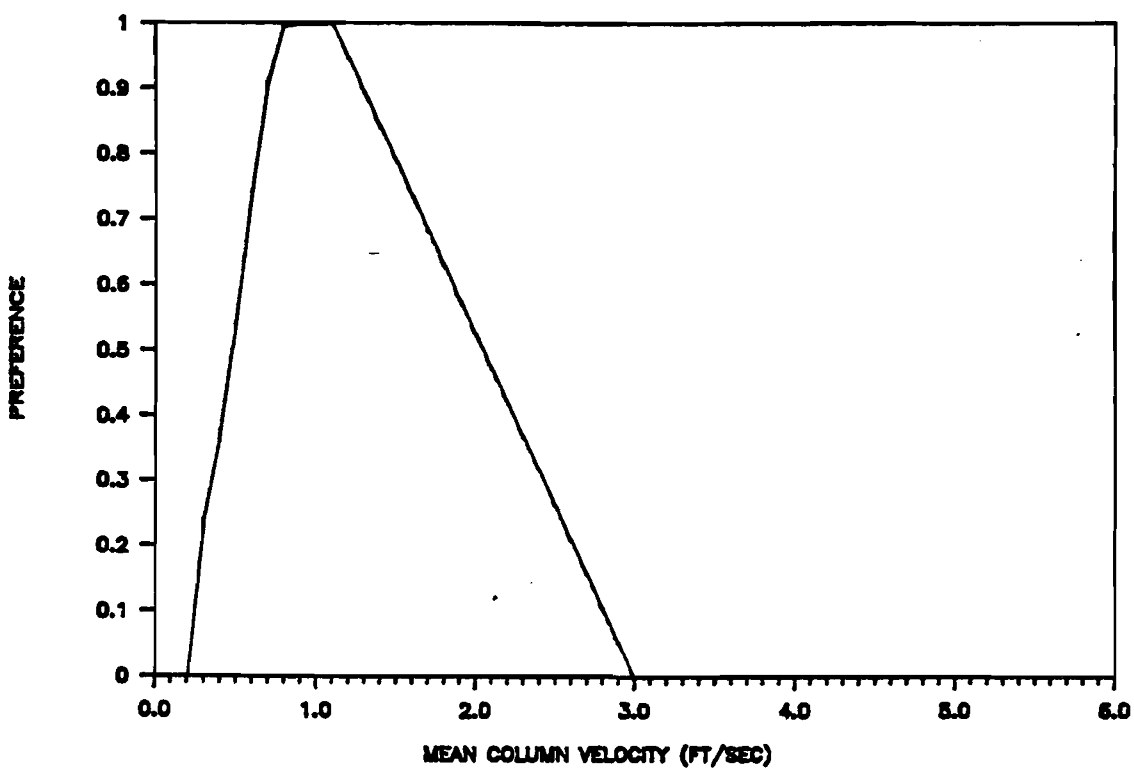
Final habitat preference criteria describing total depths and mean column velocities selected by coho salmon juveniles in the upper Trinity River, CA., 1985-1987.

APPENDIX E



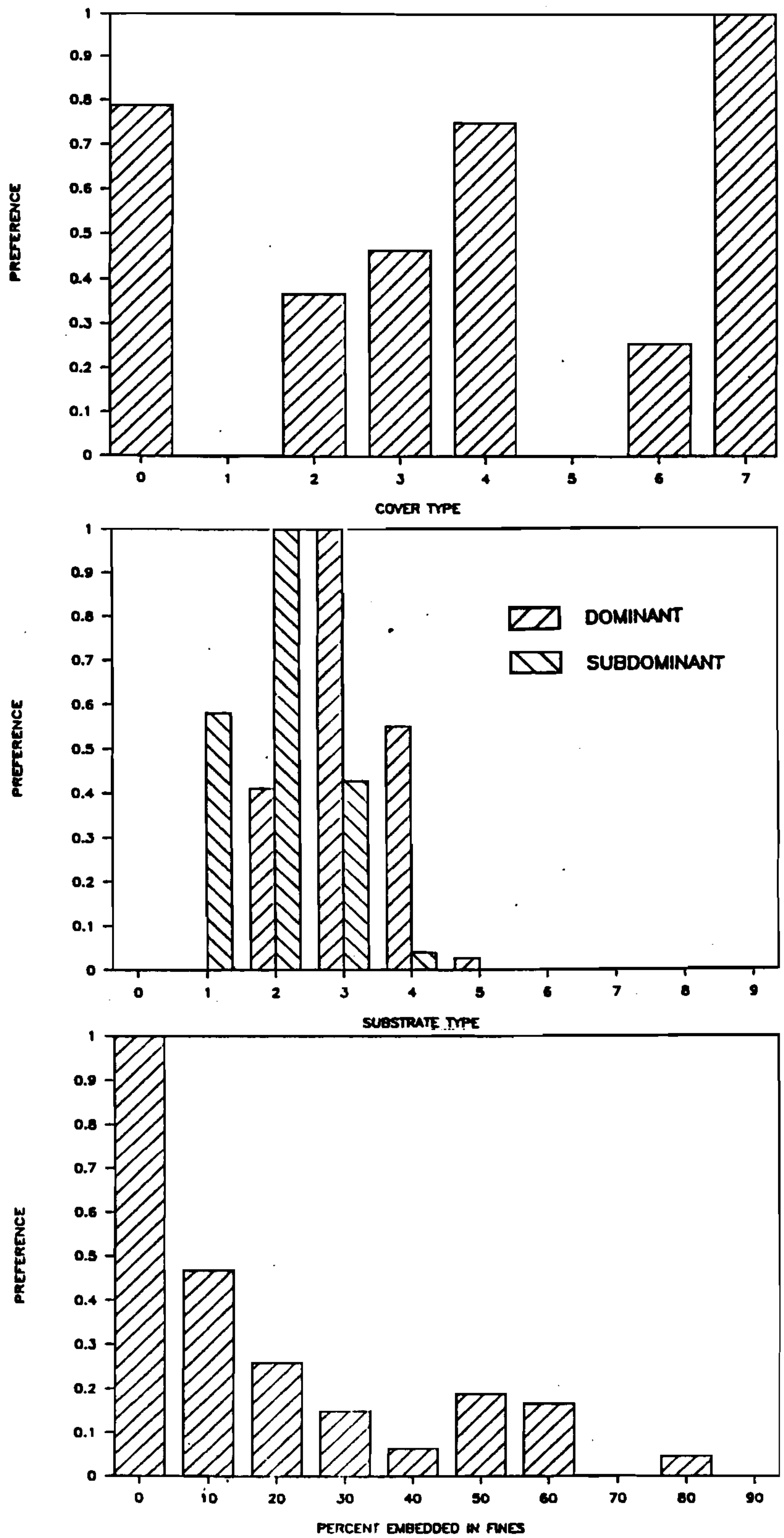
Final habitat preference criteria describing cover and substrates selected by coho salmon juveniles in the upper Trinity River, CA., 1985-1987.



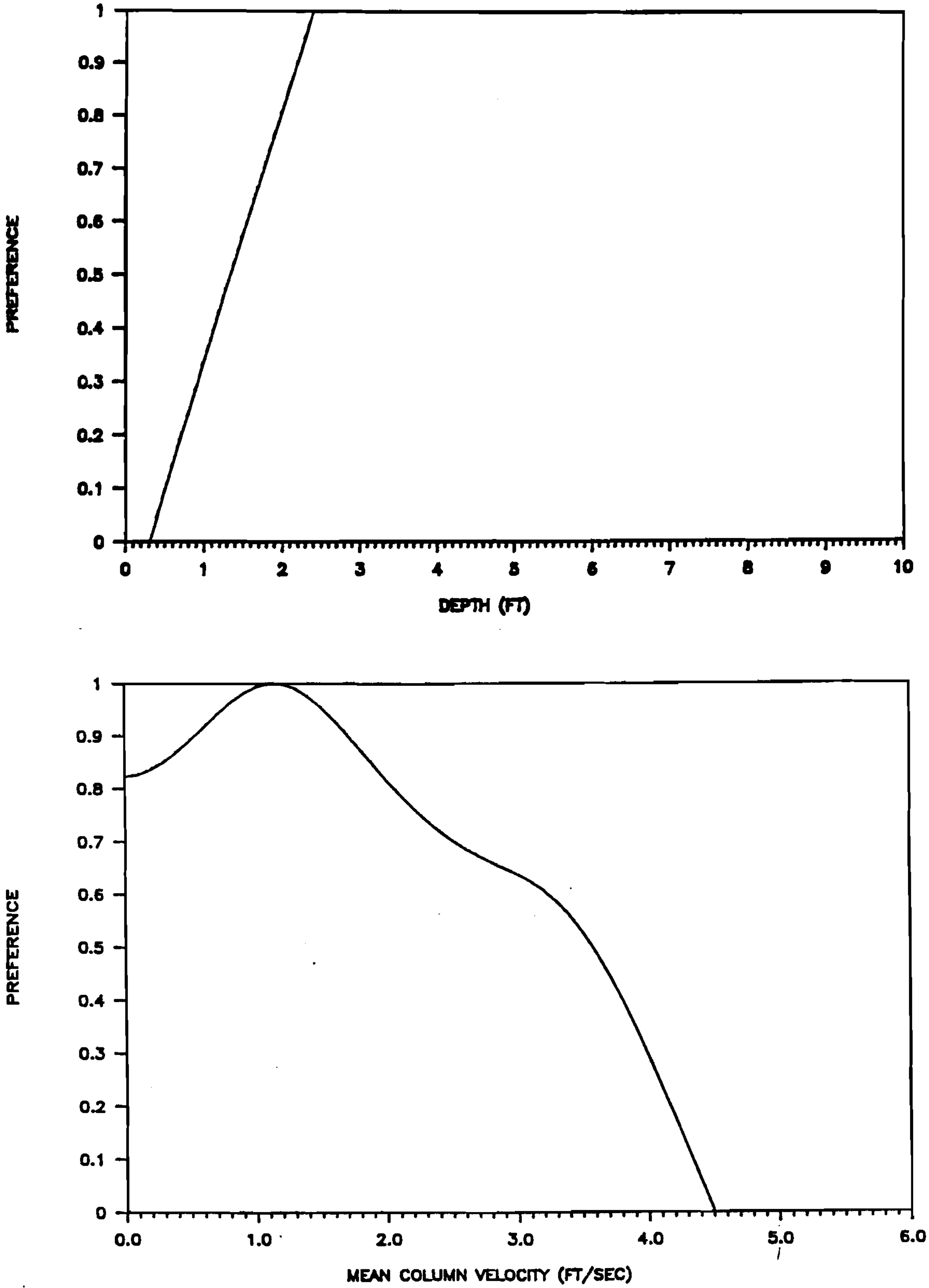


Final habitat preference criteria describing total depths and mean column velocities selected by spawning coho salmon in the upper Trinity River, CA., 1985-1987.

APPENDIX E

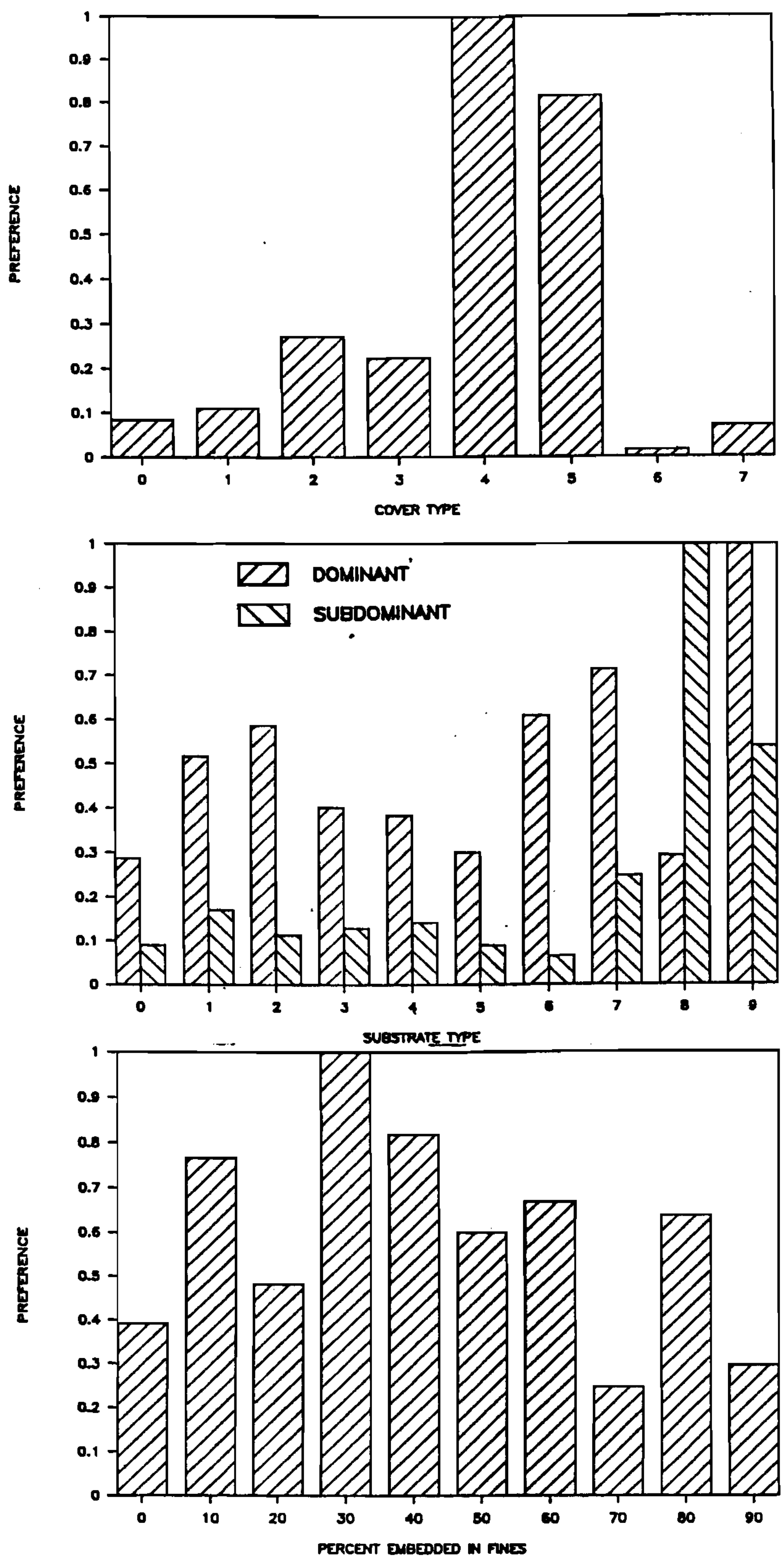


Final habitat preference criteria describing cover and substrates selected by spawning coho salmon in the upper Trinity River, CA., 1985-1987.

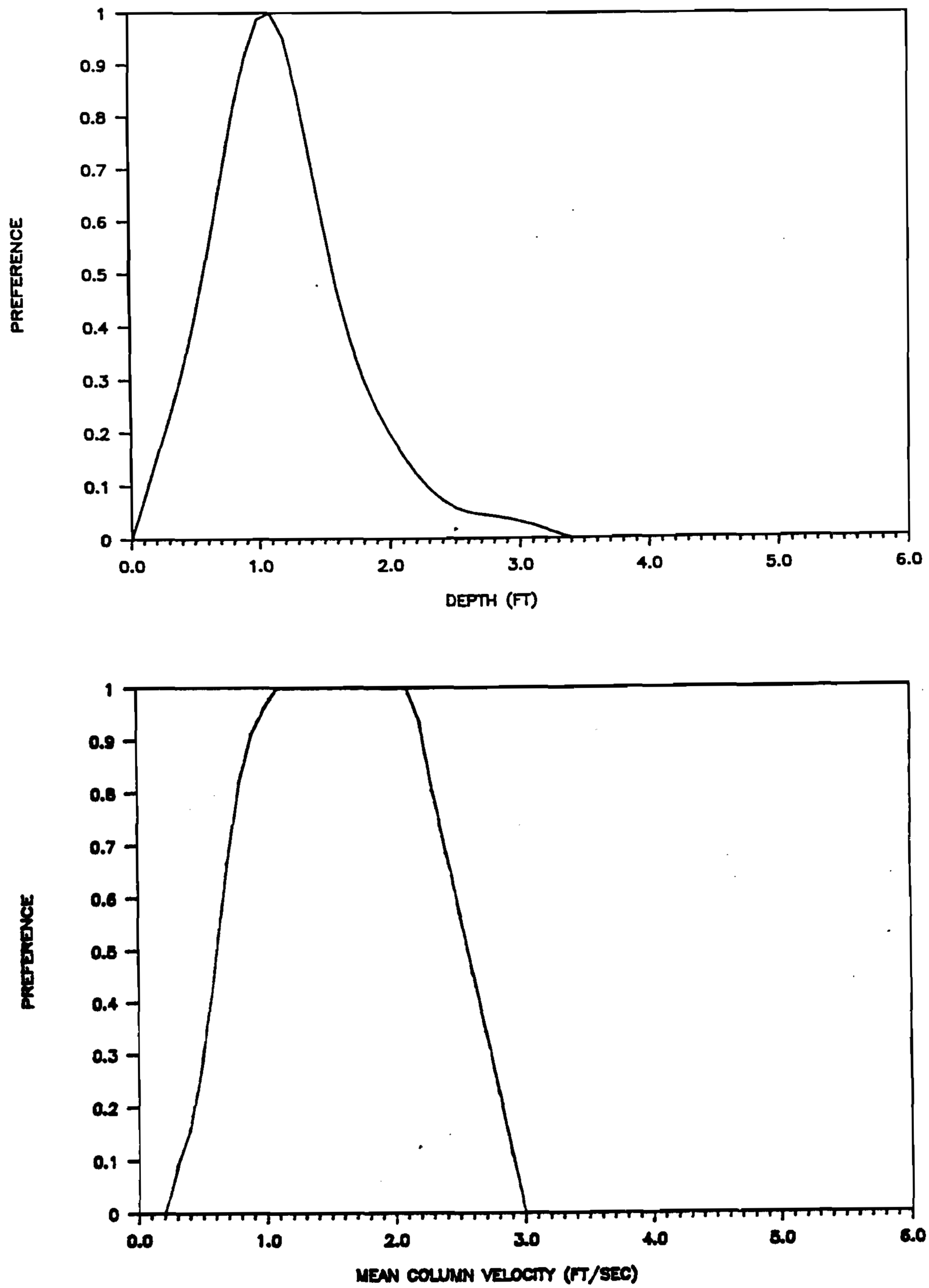


Final habitat preference criteria describing total depths and mean column velocities selected by steelhead trout juveniles in the upper Trinity River, CA., 1985-1987.

APPENDIX E

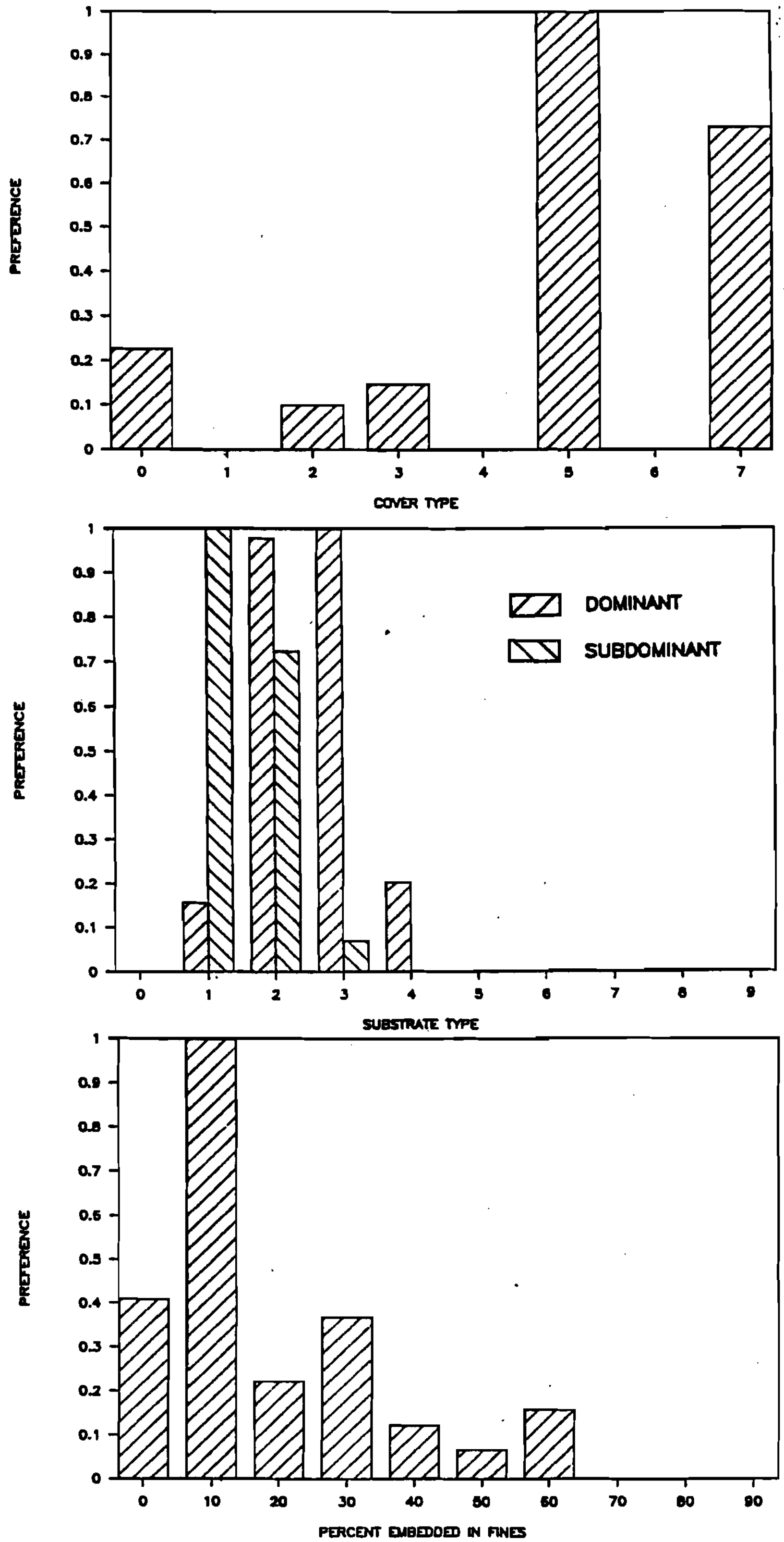


Final habitat preference criteria describing cover and substrates selected by steelhead trout juveniles in the upper Trinity River, CA., 1985-1987.



Final habitat preference criteria describing total depths and mean column velocities selected by spawning steelhead trout in the upper Trinity River, CA., 1985-1987.

APPENDIX E



Final habitat preference criteria describing cover and substrates selected by spawning steelhead trout in the upper Trinity River, CA., 1985-1987.